DISCOVERY

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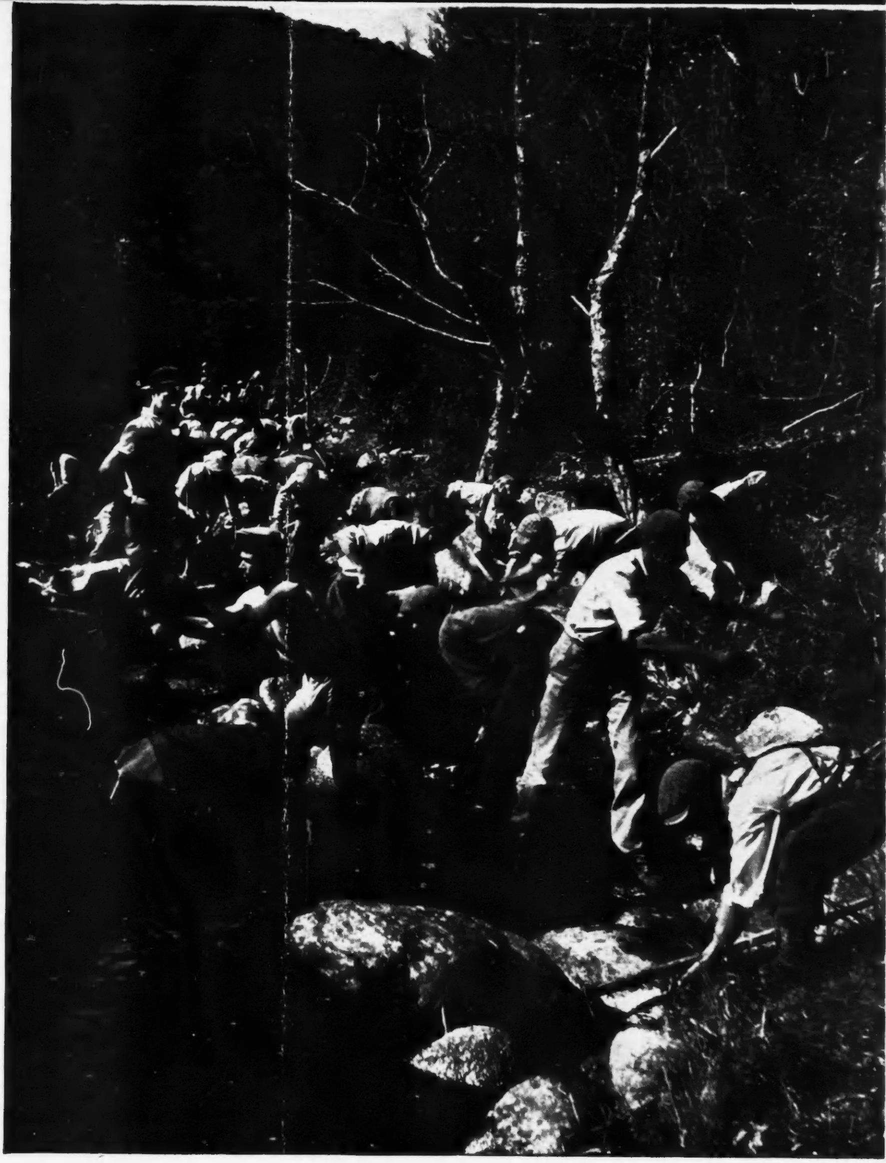

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The Progress of Science

International Laboratories

THE United Nations memorandum on "The Question of Establishing United Nations Research Laboratories" (which can be obtained through H.M. Stationery Office) is a document of the greatest interest whose purpose and scope can best be appreciated by a quotation from a resolution submitted in October 1946 by the French delegation to the Economic and Social Council:

> "There are, as a matter of fact, fields of science in which research work can only be organised efficiently and in a rational and disinterested way on an international basis. To quote one example among many: Everyone knows the importance of astronomy and astrophysics in the sum of human knowledge. Today, the majority of the observatories are to be found in the Northern Hemisphere whilst the Southern Hemisphere is very poorly equipped for this type of research work. Moreover, in the northern hemisphere, the size of the observatories is roughly speaking in proportion to the resources and budgets of the various nations. It is quite evident that considerable advantage would be gained by replacing this haphazard collaboration by systematic international action in order to locate well-equipped observatories at those sites on the globe selected as most suitable for the development of research."

It was that resolution which prompted the United Nations to organise the collection of opinions from organisations and individuals to discover which sciences could best profit from the establishment of international laboratories and to discover the best methods by which these could be organised. There are, of course, obvious difficulties. One important consideration was put forward when the resolution was first considered; the delegates of the U.S.S.R. and of the Ukraine, who commended the idea of international laboratories in principle, pointed out that, in addition to facing organisational difficulties, United Nations laboratories would not be able to draw the best scientists from the Member States.

In general there was strong support for the idea of organising international laboratories, especially from small nations who felt that such laboratories would give them access to better facilities than they could afford to provide for themselves. The variety of sciences involved and the details of the projects put forward make fascinating reading (before going on to refer to them briefly, one may note in passing an opportunity which might have been taken if history had been different. Writing in his capacity as Secretary-General of the International Council of Scientific Unions, Professor F. J. M. Stratton remarked "The development of sub-atomic energy is the kind of investigation that should have been carried out internationally had it been undertaken originally under peace conditions. One day it may come under international control and organisation.")

There are plenty of sciences to be considered in this connection. The project for an international observatory has already been mentioned, and is discussed at considerable length in the memorandum which contains statements from Professor J. H. Oort, Professor Harlow Shapley and others.

Any science which has global interests, such as Geodesy and Geophysics, has a clear interest in any proposal for the foundation of an international laboratory, and a proposal mooted by the President of the Association of Terrestrial Magnetism and Electricity for the establishment of floating laboratories, shows that we must not necessarily confine our ideas to laboratories located in one definite place. As an instance of the type of work suggested, the proposal is made that the floating laboratory should act as a mother ship and scientific base for a submarine to be employed in gravity determinations at sea. As was explained in a recent issue of DISCOVERY, gravity determinations at sea have to be made at depths below those liable to serious interference by surface sea waves. The cartographers, marine biologists, meteorologists and so forth, who also supported the general proposal either as individuals or organisations would equally well support its partial realisation in the form of the establishment of floating laboratories.

The Acting President of the Rockefeller Foundation, speaking for an Institution with unequalled knowledge of the problems of scientific organisation, favoured additional support for existing international institutions, such as the Naples Zoological Station and the Jungfrau Station, and

commented rather cautiously on possible difficulties. He emphasised the need for more trained scientific personnel and warned against a tendency to remove skilled teachers and inspiring leaders from scientifically rather backward countries. A second warning concerned over-enthusiasm in putting new institutes in countries, which being backward in science, might feel that they had a strong case to claim one of the international laboratories. He felt too that too great a measure of outside support in any country would not encourage that country to do as much as it might in supporting research.

It is, of course, essential that enthusiasm for the new project should be tempered with practical caution if success is to be achieved, and the note of warning struck in this contribution is a healthy one. Enthusiasm there is in plenty, and it is amazing how differently the same idea appears to scientists of different specialities.

Einstein, an interview with whom is reported, was cautious on the technical side, but much in favour of an institute of sociological studies which could promote a greater scientific objectivity in this field. For him clearly, the value of such co-operation is to be found mainly in its service to the human spirit and not so much in adding to the purely technical resources of scientific research. Von Karman, known for his work on hydrodynamics and aerodynamics, also saw the problem as primarily political, but made a specific proposal for an institute of fluid and soil mechanics in the Near East, where, he said, certain large territories were now less advanced in scientific technology than in the ancient time of the Babylonian Empire.

There is also a strong case for extended international co-operation in those sciences which concern the welfare of mankind, and which are seeking a world wide approach to the problems of health, both physical and mental. Dr. Dubos of the Rockefeller Institute for Medical Research submitted a long paper on problems of tuberculosis research and its epidemiology, while Dr. Pluvinage of New York proposed a plan for an international Brain Institute. Professor Gourou of Brussels, put up a programme on agriculture and living standards in the tropics while Dr. Margaret Mead of the American Museum of Natural History, proposed a project on the impact of war on children and on the development of suitable therapeutical methods.

In sum, any science which has a world-wide impact, and which could positively be benefited by a specifically international type of organisation, has a claim for consideration. The variety of topics is very great: merely to enumerate them is a thought-stimulating process. To read the proposals in detail is an education in which the chief difficulty is the digestion of the multitudinous proposals. The United Nations might have helped the reader more than a little by providing an index to this otherwise admirable volume, since, in any critical reading one is constantly needing to refer back to points of particular importance.

The Hydrogen Bomb

On January 31 President Truman gave the U.S. Atomic Energy Commission the order to continue its work on all forms of atomic weapons, including the hydrogen bomb. He gave his decision after his military and atomic energy advisers had told him the trend which atomic weapon development was likely to take. Their advice, simply and crudely put, must have amounted to this: a hydrogen bomb is theoretically possible; if America can succeed in making a practical bomb, then so can Russia; in the absence of international control of atomic weapons, America without hydrogen bombs would be militarily outclassed by a foreign power possessing hydrogen bombs. Taking all the circumstances into consideration, it is hard to see that President Truman could have come to any other decision than the one he made.

Professor H. C. Urey was the first American scientist of standing to express an opinion about the hydrogen bomb. He said: "I am very unhappy to conclude that the hydrogen bomb should be developed and built. I do not think we should intentionally lose the armaments race; to do this will be to lose our liberties, and I value my liberties more than I do my life." Judging from what has been said since by a multitude of American commentators, Urey must have been speaking thoughts common to a great section of informed American public.

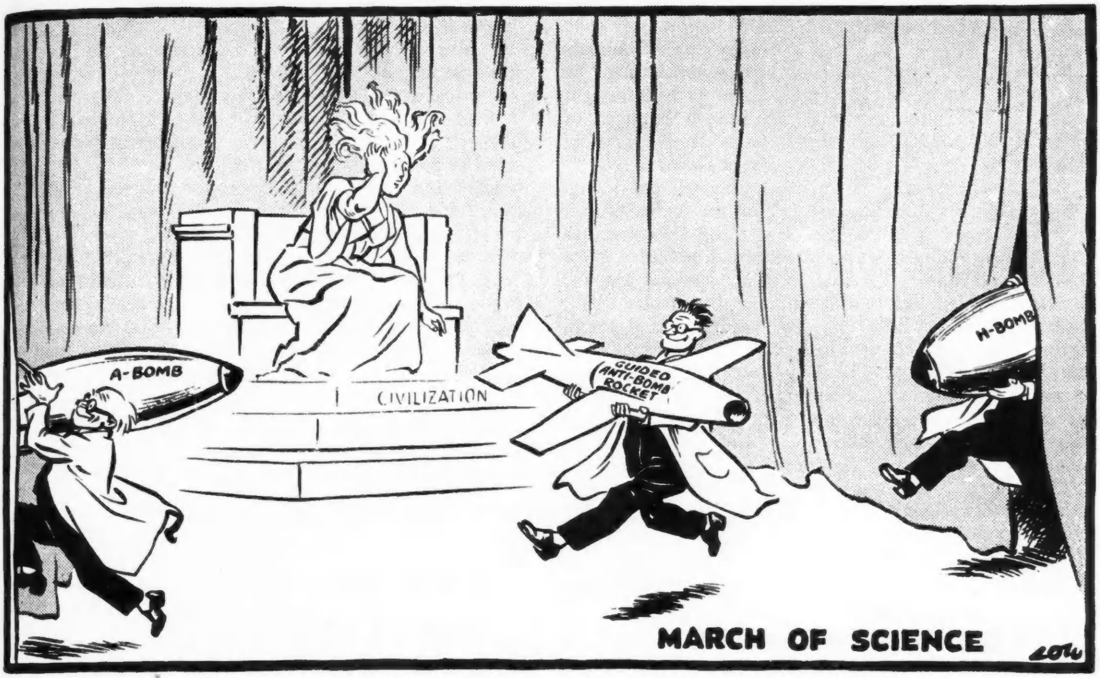
Though there was nothing comforting in the President's announcement it did some little good in that it killed a great deal of fantastic speculation. President Truman did make the public realise that the idea of the hydrogen bomb was not just newspaper talk; it made the public understand that out of the idea there might be developed a practical weapon of mass destruction, capable of devastating an area of ten, twenty or a hundred square miles instead of the area of two square miles over which an ordinary atomic bomb wrecks destruction. The President's statement must not be taken to mean that it is now absolutely certain that a practical bomb can be developed. No one can state categorically at this stage that a practical bomb can be created, any more than in 1939, after the discovery of uranium fission, could it be stated with certainty that a U-235 bomb could be made.

In this respect the statement of twelve American physicists issued on February 5 at the annual meeting of the American Physical Society (and quoted in *The Times* of February 6), was a shade misleading, but one fact of importance that can be taken from that statement is that once a hydrogen bomb is designed and exploded, then the destructive power of such bombs could be increased considerably for "the thermo-nuclear reaction on which the H-bomb is based is limited in its power only by the amount of hydrogen which can be carried in the bomb".

The concept of a hydrogen bomb is by no means new. It has been discussed for a long time among nuclear scientists and a few popular books (notably the one by Prof. Thirring of Vienna, which Prof. P. M. S. Blackett quoted extensively in *Military and Political Consequences of Atomic Energy*) have indicated to the lay public that a hydrogen bomb might lie within the realms of possibility.

There has been a lot of talk about the hydrogen bomb depending on the same catalytic process that converts hydrogen into helium in the sun. This reaction is a slow one and, as Prof. O. R. Frisch said in a B.B.C. talk last month, it proceeds at too leisurely a pace to provide the basis for a bomb.

The most feasible reaction for the bomb would seem to be the well-known reaction in which two deuterons (i.e. nuclei of deuterium or 'heavy hydrogen') fuse together to



Low's comment on the hydrogen bomb.
(By arrangement with Evening Standard: World Copyright.)

form the light helium isotope according to the following equation:

$${}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} = {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} \quad (\textit{neutron})$$

There is a destruction of mass in the process, and consequently the reaction proceeds with the liberation of an enormous amount of energy. It was this reaction which Gamow had in mind when he wrote (in *Atomic Energy in Cosmic and Human Life*, Cambridge University Press, 1947): "A small charge of deuterium could be used as an explosive with tremendous destructive power if only we could devise the means for raising its temperature instantaneously to well above one million degrees." This reaction has been studied in the laboratory, where it can be produced by bombarding heavy water (which contains an abundance of deuterons, of course) with deuterons that have been accelerated in a cyclotron. Equally energetic deuterons could be obtained by subjecting them to a sufficiently high temperature. Here then is a theoretical basis for a hydrogen bomb; if a uranium or plutonium bomb is exploded inside a large quantity of deuterium or of a deuterium compound, then it should generate a temperature high enough to bring about the reaction described above. In other words the conventional atomic bomb would become the detonator for the hydrogen bomb.

Essential raw material for the making of a hydrogen bomb would therefore appear to be heavy water or deuterium oxide. In ordinary water the ratio of water containing hydrogen of atomic weight to heavy water is 99·98% to 0·2%, but it is possible to concentrate the heavy water by electrolysis and by other methods. Production of heavy water on a large scale has been carried out in America and Norway, and it has also been produced in fair quantities in Britain, Germany and Russia. The concentration of heavy water is by no means a simple process (as readers will see if they consult the passages on p. 101 of the Smyth Report), and the cost of producing it in really large quantities would account for part of the huge amount of money which it is estimated that America will have to spend on the hydrogen bomb project. (Prof. Urey's estimate, for instance, is £100 million.)

One story which has gained much publicity suggests that it is the third isotope of hydrogen, the radioactive isotope called *tritium*, which would be the basis of the hydrogen bomb. This appears to be something of a red herring. Tritium would be involved, no doubt, but only as a *by-product* of the explosion. When deuterons meet deuterons at a high temperature the main reaction that occurs is the one described earlier. Some tritium is formed however according to the following equation:

$${}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} = {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$$

In the American lay press (notably in *Time* of Feb. 13) there has been talk of an explosive reaction involving lithium and tritium (which react to give 2 helium nuclei and a neutron) but no expert opinion on this idea has yet been published.

So much for the technical considerations of the hydrogen bomb, which seem of very minor importance when compared with the political considerations. Doubtless great effort on the part of scientists and technicians will be put into the hydrogen bomb project, but let us hope that this effort will be eclipsed by what is done in the sphere of international politics to prevent the bomb from ever being brought into use. Any means that can be found that offers a means of halting the atomic arms race is worth examining. As Senator McMahon, chairman of the Joint Atomic Energy Committee of the U.S. Senate and Congress, has said, no suggestion in this direction should be turned down as being too startling for consideration. His own idea for breaking the deadlock over atomic energy control is a bold one, and even if it cannot be accepted as it stands, it should certainly be examined very closely for it may offer the basis for a practical plan. The McMahon proposal is that America and the rest of the world should curtail armament expenditure by two-thirds, and with this he coupled the suggestion that 10,000 million dollars a year which America could thus save should be administered by the United Nations as an international 'Marshall Aid' fund for the benefit of all nations including Russia, if the nations agreed to two conditions. These conditions should be as follows:

First, general acceptance of an effective programme for the international control of atomic energy; second, agreement by all countries enforced through inspection that two-thirds of their present spending upon armaments be devoted towards constructive ends.

There has been some justifiable criticism of the proposal, but it cannot be turned down on the grounds that it is unrealistic in its approach to the problem. The guarantees which Senator McMahon asks for involve close inspection of arms factories and atomic plants, which is recognised as the absolute minimum for any scheme for international disarmament if it is to be of any real value.

The Structure of Clouds

Most of us take the beauty of clouds for granted and assume, without giving it much thought, that it is a beauty of massed light and shade. Yet when we look more carefully we discover that it is also the beauty of design. Many clouds are arranged in intricate and highly regular patterns, and these patterns are not only an inspiration to the artist, but also a challenge to the scientist who is called upon to explain their origin.

Fig. 2 (*a*) shows an overhead alto-cumulus cloud on a fairly clear day. It is seen to consist basically of a crowd of polygonal cells, the body of each cell being filled with cloud and its dark boundaries being comparatively clear air. For greater clarity a few of the cells are drawn in outline in Fig. 2 (*b*).

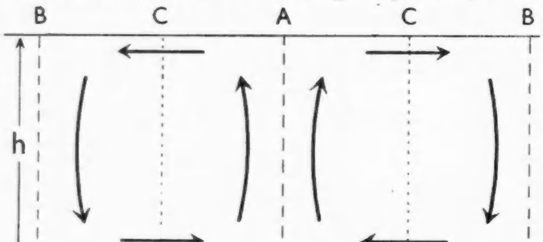


Fig. 1.—The circulation of fluid in a normal Bernard cell.

A plausible explanation of this design comes from the study (carried out by H. Bernard and later by P. Idrac and T. Terada) of the patterns arising from convection currents in fluids. If a fluid is heated below and cooled above, then it becomes more dense on top, and so there must be a constant flow of the upper layers towards the bottom and of the lower layers towards the top. It is found that this circulatory system actually breaks up into a number of separate cells (called Bernard cells, after their discoverer). Fig. 1 illustrates the circulation within a typical cell; the movement is upward at the centre, radially outward along the top, downward at the periphery and inward at the bottom. Suppose, then, that the region in which a cloud is situated is also warmer below than on top; there will be an air circulation, which will break up into a number of cells of the type just described. The white cloud material would tend to concentrate in the regions C, C, and to be swept away from the regions A and B, B, leaving dark spaces at the centre and periphery of each cell. However, if the cloud material is abundant, the regions C tend to join up, so that there is no clearly defined dark centre at A. The appearance of Fig. 2(*a*) is clearly consistent with a generation of the pattern in this way. The central dark spot only appears in a few cells, for example the one drawn on the top left in Fig. 2 (*b*).

However, one cannot be satisfied that the theory is a good one unless it enables one to synthesise cloud patterns at will.

A synthetic investigation has been carried out by K. Chandra and is reported by M. W. Chiplonkar in *Endeavour* (October 1949). The apparatus consists of a long shallow chamber of variable depth, closed at the bottom by a metal plate that can be uniformly heated and at the top by a glass plate which permits inspection. Tobacco smoke is used, in place of the cloud material, to make the various patterns visible. Fig. 2(*c*) shows the pattern obtained when the depth of the chamber was 7 millimetres and the difference of temperature between top and bottom was 130° C. The cells and especially their centres are now much more clearly defined and more regular, but otherwise the resemblance between this artificial pattern and the real cloud of Fig. 2 (*a*) is very marked, so that the general theory is verified by this synthetic experiment.

Sometimes the circulation in the cells is reversed, being downward at the centre and upward at the periphery. In this case the cloud tends to collect at the boundaries between the cells giving a network of thin white lines enclosing dark cell areas. This pattern, too, can be reproduced in the laboratory.

In the cases so far described there was little if any wind, and so the clouds were not being acted on by horizontal shearing forces. Correspondingly, no horizontal movements were used in the experimental imitations. But when a wind is blowing and the clouds are therefore subjected to shearing forces, new patterns emerge, one of which is shown in Fig. 3 (*a*), a photograph of low alto-cumulus clouds. The wind was blowing the clouds in the direction shown by the arrow in Fig. 3 (*b*). Here the basic structure is a series of rolls, the front of each being sharply defined. Within each roll there are rudimentary signs of the polygonal cell structure which we met above. To reproduce this

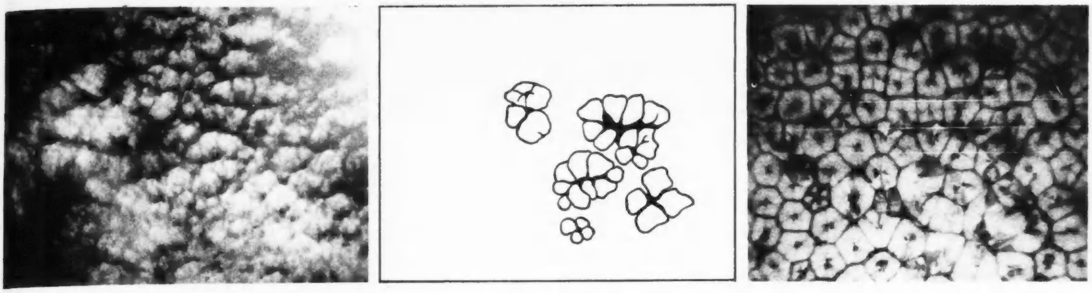


FIG. 2.—(*a*) Polygonal cell structure in an overhead alto-cumulus cloud in still air and (*b*) outline drawing of some of the cells. FIG. 2 (*c*) a similar structure artificially created in the laboratory.

pattern the chamber was made 12 millimetres deep and the temperature difference between top and bottom set at 95°C. To represent the shearing action of the wind the glass plate was moved slowly from left to right, and the result was the remarkable imitation shown in Fig. 3 (*c*). In another pattern that sometimes occurs in winds, the cells are well defined, but are now arranged in rank and file; that is, the centres of the cells lie at the intersections of two sets of parallel lines.

Cui bono? The question does not have to be answered for every separate scientific investigation, but when there is an answer it is welcome. Surely a knowledge of the fundamentals of cloud structure will help the painter and the cloud photographer.

This work shows that cloud patterns will reveal the wind structure in and around them; its significance is not likely to escape the meteorologist, and possibly the air pilot will be able to make use of the connexion between wind and cloud form. Indeed glider pilots have already come to know that certain patterns of cumulus clouds indicate a series of ascending currents, and they gain height by hopping from one of these lifts to another.

A Constant that Varies

FROM the early days of research on radioactivity it has been believed that the rates of radioactive decay of elements (usually expressed in terms of the half-life of the element, the time within which half of any given number of atoms will have disintegrated), were constants for each element and were unaffected by chemical forces. That is to say, the half-life of radium is 1690 years, whether the radium is in the form of the metallic element or combined in a compound such as the bromide or sulphate. The discovery of artificial radioactive elements did not alter this belief, and in fact the use of these substances in tracer experiments depends on the fact that the radio-isotope can be identified by measuring its half-life no matter what chemical compound it has entered into.

In most radioactive decay processes a particle is expelled from the decaying nucleus, either a neutron, a proton, a helium nucleus, an electron or positron. There are, however, a few cases in which the nucleus captures an electron from the outer shells of the atom, and simultaneously emits a γ-ray. For example an artificial radioactive isotope of manganese Mn^{54}, made by bombarding iron with deuterons, decays to chromium (Cr^{54}), with the emission of a γ-ray, by capturing an electron from the innermost orbit of extra-nuclear electrons.

The decay probability for this kind of radioactivity is proportional to the electron density within the nuclear field, that is within a very short distance of the nucleus itself. For most heavy atoms this electron density is not affected by the state of chemical combination of the atom because it is only the outermost electrons which take part in chemical bond formation while the capture takes place from the innermost orbit containing two electrons. The intervening electrons are an effective shield.

There is one light element, beryllium, which has an isotope that decays by electron capture. Be^7, which is produced by bombarding lithium with protons, decays back to lithium with a half-life of forty-three days. An isolated beryllium atom has only four extra-nuclear electrons, two of which are readily lost in certain beryllium compounds.

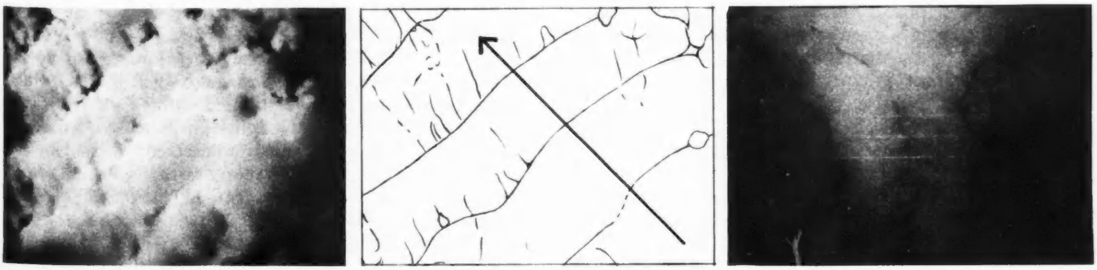


FIG. 3(*a*).—A very low alto-cumulus cloud with thick rolls formed at right angles to the direction of the wind indicated by the arrow in Fig. 3(*b*). FIG. 3(*c*) laboratory imitation of this roll structure.

In 1947 E. Segré in America and P. Daudel in Paris independently suggested that there should be a detectable difference in the radioactive decay rates of Be^7 when the beryllium was in the form of the metal and when it was combined as oxide or fluoride. The experimental verification of this prediction proved difficult and the first experiments were inconclusive. Recently, however, both these workers, independently and simultaneously, were able to show that there was indeed a difference. Daudel found that the half-life of Be^7—in the form of beryllium chloride—was about five parts in 1000 longer than that of Be^7 metal, while Segré found that it was about two parts in 1000 longer for beryllium fluoride than for the metal. The agreement between these values is quite sufficient to justify the statement that the effect is a real one. However, the extreme difficulty of its detection and the very special nature of the elements involved show that this is indeed the exception that proves the rule, and that in all normal tracer experiments with heavier atoms there will be no difficulty in identifying atoms by measurement of their half-lives.

REFERENCE

Physical Review, 1949, **76**, 897 and 1000.

Cortisone and ACTH

THE discovery of the remarkable effectiveness of cortisone in the treatment of rheumatoid arthritis has stimulated what is probably the most intense and world-wide research upon a drug since the war-time work on penicillin. Almost daily there are reports of new developments, confirmation (and sometimes denials) of previous claims or news of new research projects being started.

The convenient abbreviation 'ACTH' has been appearing in the literature dealing with these researches with increasing frequency during the last few months. It stands for *adrenocorticotropic hormone*, and is a material which has been shown to produce as excellent a response as cortisone in rheumatoid arthritis patients. The two drugs are linked biochemically in the following manner. The outer portion of the adrenal glands—the *cortex*—produces a number of different hormones, including cortisone, which are secreted into the blood and have various actions, (*see* Dr. Geoffrey H. Bourne's article in DISCOVERY, January 1950). Almost thirty different compounds of the class known as 'sterols' (which are alcohols of high molecular weight) have already been isolated from the adrenal cortex, although not all appear to be active physiologically. The adrenal cortex can be stimulated to produce increased amounts of the cortical hormones by a special hormone, the hormone already mentioned and known as ACTH, which is secreted by the pituitary gland. Administration of ACTH can thus produce indirectly results similar to those following injection of cortisone, although ACTH may produce other effects as well, as it seems to stimulate production of the other cortical hormones besides cortisone. Clinical experience has shown that ACTH is an extremely powerful drug and must be administered with great care as it can cause unfavourable side effects. ACTH is being made in the Armour Laboratories in Chicago at the rate of 60 lb. a year from hog's pituitaries, which is sufficient for the treatment of 2000–4000 patients.

The supply of ACTH from slaughter houses can be expanded but must inevitably be limited and so the possibility of laboratory synthesis of the material has been considered. Unfortunately, ACTH is a protein; owing to the size and complexity of its molecule, a complete determination of the structure and a synthesis is beyond the scope of organic chemistry at present. However, Dr. Chor Li of the University of California has shown that the large molecule can be broken down into smaller and simpler fragments, called peptides, some of which retain the original activity. He has in fact obtained one such peptide that is 16 times more potent than ACTH, and it may prove possible to synthesise this substance.

Research upon cortisone is following two main lines. There is the search for an improved method of laboratory synthesis as those in use at present are extremely costly and difficult (*see* DISCOVERY, December 1949, p. 369). Already the discovery of a new method has been reported by the Gidden Company of Ohio, who have also prepared several compounds closely related to cortisone starting with soya-beans. The other line of approach is the effort to find equally effective substitutes for cortisone which are more amenable to laboratory synthesis.

The Jubilee of the N.P.L.

THE National Physical Laboratory (a long account of whose history was given in DISCOVERY, May 1946) attains its jubilee this year, though no large-scale celebration is intended until 1951, the year of the Festival of Britain. Started in 1900 as a result of the demand for reliable standards and authoritative tests in applied physics and engineering, it grew to maturity under the enthusiastic leadership of Sir Richard Glazebrook, the first director (1900–19). His original team consisted of eight scientists, four mechanics and engineers, one power-house engineer, and the porter and housekeeper. It has developed into a staff of more than a thousand civil servants, and the N.P.L. now ranks as one of the chief standardising laboratories of the world. Many members of its staff are known internationally in their own fields, and many serve as technical advisers on government committees and standardising committees such as those of the British Standards Institution. Of the original team, several have achieved fame and honours. One of them, Sir Frank Smith, who lives in retirement not far from the N.P.L. laboratories at Teddington, designed the Lorenz apparatus used there for the accurate determination of resistance in absolute units.

Time has brought development of the N.P.L. There were originally two departments (later called 'divisions'), namely, Engineering and Physics. Seven were in existence when Glazebrook retired; today there are ten, including the new Mathematics Division established in 1945. (The most publicised activity associated with this division was the construction of a "Noughts and Crosses" machine. This was in fact a spare-time amusement devised by Dr. Davis for the staff children's party at the N.P.L., and not, as many people may have surmised, an official piece of research.) A Test Section and an Electronics Section have been formed recently.

Many tests had hardened into routines, and accumulations of tests, so vitally necessary for industry, sometimes held up the work of research. A start has therefore been

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FIG. 1.—Air view of Eiziksjokull, one of the smaller jokulls or permanent ice-fields of Iceland, with its domed cap of snow and ice and its steep rocky sides. It was probably elevated *en bloc* by faulting.

Natural History in Iceland

JULIAN HUXLEY, F.R.S.

IN Iceland last summer a number of new facts and experiences, interesting and exciting to a naturalist, came my way—some of them through my own eyes, others through the mouths of the able Icelandic zoologists who put so much of their time and knowledge at the disposition of James Fisher and myself.

Thus we saw various species that were new to us, and sometimes spectacular to look at, like the harlequin duck.* That was exciting enough; but the interest was multiplied when we remembered that it is an essentially North American bird, one of the rarest stragglers to Europe, and yet here breeding close to familiar British ducks like mallard, tufted duck, wigeon and pintail. We found a meadow pipit breeding in a wood, like a tree pipit, instead of on the customary open heath; and what is more, singing a song half-way to a tree pipit's.

We saw some local birds recognisably different from their British congeners, like the Iceland redshank, which is several shades darker than ours. We saw a Painted Lady butterfly in the northern half of the island—a truly astonishing sight, since its nearest permanent breeding-place is the south of France. We got evidence, from our own counts, of the increase of the gannet; and from our Icelandic colleagues of the fact that not only it but nine or ten other birds have been rapidly extending their range northwards during recent decades.

But the modern naturalist is not content unless he can relate his facts, however valuable, and his isolated experiences, however exciting, to general principles; and the very vividness and novelty of the impressions made by an unfamiliar country will set his scientific imagination to work. Here is the result of my own case—some of the ways in which Iceland's natural history illustrates or illuminates evolutionary biology in general.

* A list of the Latin names of the birds mentioned is given at the end of the article.

Undoubtedly the most exciting of these is the light which it sheds on the world-wide change of climate now in progress: but this I shall keep to the last.

The most obvious point is the paucity of bird species in general, and of passerines (song-birds, etc.) in particular. Thus the number of regular breeding species in Iceland is only a little over a third of that in Britain; but the number of breeding passerines is less than one-eighth of the British. In part this is due to the unfriendly climate and the barrenness of much of the island. Although Iceland barely touches the Arctic Circle, real trees cannot grow except in two small sheltered localities, and both vegetation and insect life have much less luxuriance and variety than with us: while the winter, of course, is such that very few species of bird could possibly live through it.

In Spitsbergen, further polewards, we find a marked further drop, both in the total and the passerine percentage. The best way to bring this home is by means of a table:

TABLE I
BREEDING SPECIES OF BIRDS IN BRITAIN, ICELAND AND SPITSBERGEN

	Latitude	*Regular breeding species*	*Passerines*	
			(a) number	*(b) % of total*
Britain	49° 57′–58° 40′ (mainland) 49° 51′–60° 51′ (with islands)	186	77	41·4
Iceland	63° 20′–66° 32,	69	9	13·0
Spitsbergen	76° 26′–80° 50′	25	1	4·0

There is, however, also the fact that Iceland is an island, and a fairly remote one, lying over 500 miles from the

Hebrides (a little more from Cape Wrath, the nearest point of the British mainland), and close on 300 miles from Faeroe. Admittedly the distance north-westwards to the Greenland coast is under 200 miles; but Greenland, especially in these latitudes, is so forbidding that very few species can have used it as a stepping-stone to Iceland.

Now remote islands invariably show a fauna and flora which is impoverished compared to that of the nearest mainland. This is usually set down to the difficulties presented to birds by a long sea passage, especially to small terrestrial species or those with feeble flight. In addition, an island is likely to have fewer kinds of habitats than a mainland area, and this may cut down the number of species which can find a permanent niche in its biological economy, even if they manage to reach it.

It is of course difficult to say just what birds are lacking merely because they have failed to overcome the sea-barrier. Some apparent candidates turn out on reflection to be ruled out for other reasons. Thus the fact that among the thrushes, the redwing breeds in Iceland and the fieldfare does not, is not so surprising when we remember how the fieldfare seems much more definitely wedded to tall trees to nest in, and (we may presume at least partly for that reason) does not exist so far north in Scandinavia as the redwing.

Then, with such a favourite as the meadow pipit to parasitise, it is at first sight puzzling that there are no cuckoos. It seems probable that the reason is the low density of pipit population. A cuckoo has to keep about a dozen fosterers' nests under observation if it is to succeed in its parasitism: and this would be impossible in Iceland.

The absence of the rock dove seems also surprising—until one remembers that the species seems to be dependent on weed-seeds and other by-products of human cultivation.

But I do find it puzzling that the ring ouzel, which likes rocky slopes and in Norway breeds as far north as the North Cape, has not established itself; and still more so

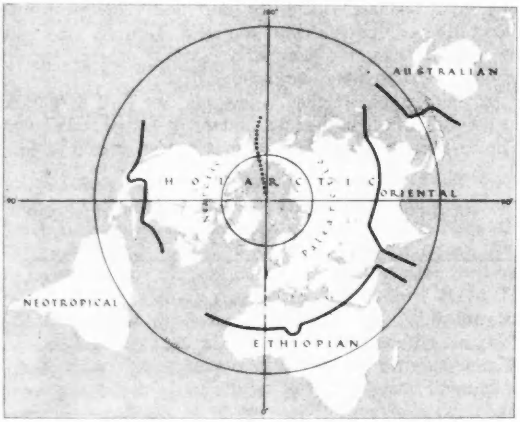


FIG. 2.—Main zoogeographical regions characterising the distribution of the land animals of the world. The Holarctic is normally divided into two sub-regions, the Palearctic (Old World) and Nearctic (New World). In addition, there are separate ocean regions characterising the distribution of marine forms, including sea-birds; of these only the Atlantic region concerns us.

that the dipper is absent, when its smaller relative, the wren, has been breeding in Iceland so long that it has evolved into a distinctive subspecies. Of course the streams by which the dipper lives would be frozen over in winter; but some of the dipper population of northern continental Europe migrates southwards in winter, and the same might readily have occurred in Iceland, while the rest might have done what all the Iceland wrens do, namely take to the sea-shore. And I am pretty sure that if the house sparrow ever reached Reykjavik, the capital of Iceland, it would flourish and multiply.

The greatest puzzle, perhaps, is that posed by the Lapland bunting, which breeds in Greenland and north of the Arctic Circle in Norway, but not in Iceland, although it seems to traverse the island regularly on passage!

That for strong fliers the climate is the only obstacle is shown by the fact that since the beginning of this century, the list of breeding species has been increased by nearly 10%, undoubtedly owing to an amelioration of the climate —a fact to which I shall return.

Again, swallows come to Iceland every summer (we saw some in the Westmann Islands) as do willow warblers, but neither species has yet been found breeding.

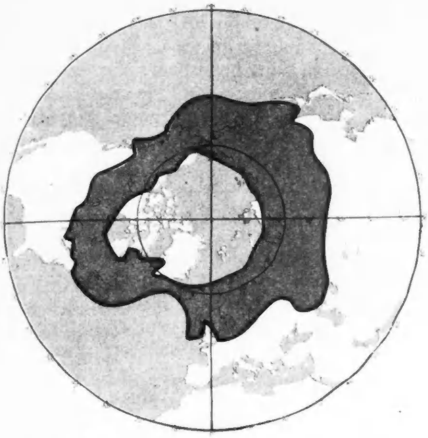
It seems that many species are all the time sending out scouts, so to speak, into areas where breeding is impossible but on the chance that one day they can establish themselves permanently. This seems a wasteful method, but natural selection always involves wastage. The most striking example is the Painted Lady butterfly (*Vanessa cardui*), which cannot reproduce itself regularly through the winter north of Southern France, but in most years sends out vast numbers to Britain and other countries. The one we ourselves saw, by Lake Myvatn, was nearly 1500 miles outside its permanent range!

Another interesting feature of broad geographical distribution is this—that Iceland is at the same time the westernmost outpost of a number of Old World bird species and the easternmost of some (but fewer) New World ones. Actually Lake Myvatn is the area of maximum overlap between the bird faunas of what zoologists call the Palearctic and the Nearctic regions, northern Eurasia and North America respectively.

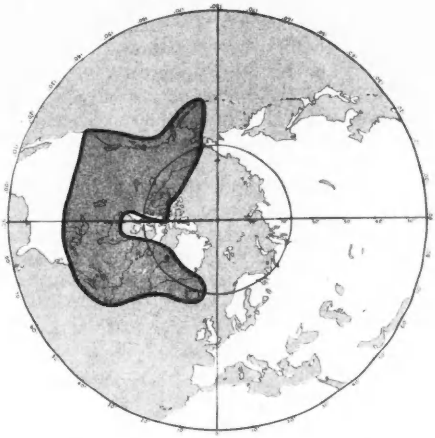
Thus Iceland is the western limit of breeding range for such Old World species as whooper swan, greylag goose, snipe, golden plover, whimbrel, redwing, white wagtail (and indeed the entire wagtail genus); but it is the eastern limit for the otherwise New World species, great northern diver, Barrow's goldeneye and harlequin duck. The ducks, by the way, well illustrate the complexities of geographical distribution—Iceland shows us not only several Old World species at their western limit, like wigeon, teal, common scoter, and tufted duck, but also a number of circumpolar or Holarctic species such as mallard, pintail, gadwall and shoveler.

It is noticeable that all the New World species which breed in Iceland are hardy enough to inhabit parts of Greenland also. If the Labrador Current did not cool the east coast of Greenland and northern Canada so much below the temperature they ought to enjoy by virtue of their latitude, and the Gulf Stream did not warm Iceland and Spitsbergen and the north-west coasts of Europe so much above it, the contribution from the New World would presumably at least equal that of the Old.

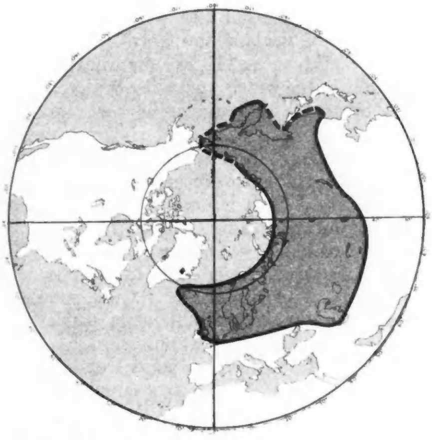
FIG. 3. *a–d.*—Types of geographical distribution of Iceland birds.



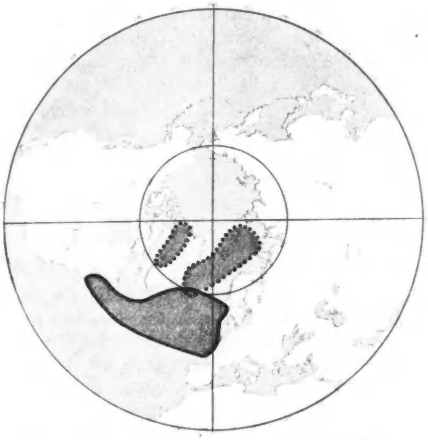
(*a*) Breeding and distribution of a Holarctic species, the Red-breasted Merganser: its breeding area extends in a ring round the entire north-temperate zone.



(*b*) Breeding distribution of a Nearctic species which extends to Iceland—the Great Northern Diver or Loon.



(*c*) Breeding distribution of a Palearctic species, the Wigeon, which extends from Behring Straits westwards, to overlap with the Great Northern Diver (FIG. 3, *b*) in Iceland.



(*d*) Breeding distribution of two Atlantic species, the arctic Little Auk and the north-temperate Gannet: the two just overlap in north-east Iceland.

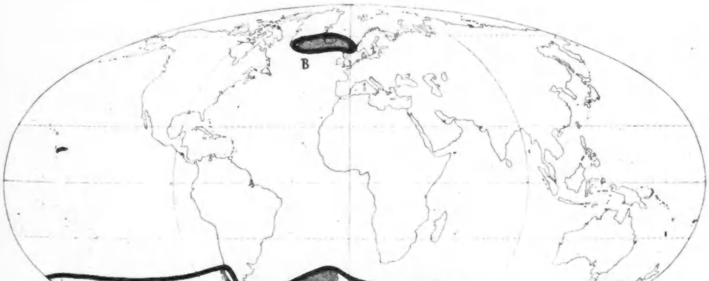


FIG. 4.—Breeding distribution of the Great Skua, a circumpolar species from the southern hemisphere, which has given rise to one northern-hemisphere subspecies. (The shaded parts represent the actual breeding-areas of the various southern hemisphere subspecies.)

Figs. 3 and 4 are based on maps compiled by James Fisher.)

There is, by the way, at least one plant in Iceland which is of New World origin. The sea-rockets, *Cakile*, are shore-dwelling crucifers with lilac flowers. Two Icelandic botanists, Dr. and Mrs. Löve, have recently shown that the sea-rocket of Iceland does not, as had been generally assumed, belong to the species found in Scandinavia and with us in Britain, *Cakile maritima*, but reveals itself, both by its slightly different form and its doubled chromosome-number—36 instead of 18—as the North American species, *C. edentula*. This holds also for the sea-rockets of the Azores. The Löves' conclusion is that the Gulf Stream has been responsible for the appearance of the American sea-rocket in these otherwise Old World islands, by transporting the seeds in its slow warm drift.

At various times in the geological past, there was a land connection between the Old and the New Worlds across what is now the Behring Straits, and probably also, though not so often or so long, across the North Atlantic, along the line still indicated by the submarine ridges between Greenland, Iceland, Faeroe and Shetland. The climate in the regions connected by these land-bridges was then less rigorous, and there was more uniformity of animals and plants in the Holarctic region than now. But isolation and time saw to it that the inevitable differences were accentuated, and meanwhile the New World fauna received large additions from the Central and South American region, which were very different from the immigrants that the northern Old World received from Africa and south-western Asia. Thus eventually two quite distinct faunas and floras, the Palearctic and the Nearctic, were differentiated—distinct, but with a number of elements obviously of common origin, and still with a considerable number of species shared by both and therefore classed as if Holarctic.

The greater isolation of the two regions today may possibly be due not only to the breaking of the land-bridges between North America and the Old World, but to an actual increase of the distance across the Atlantic, caused by the slow drifting away of America from Europe.

This was postulated by Wegener in his theory of Continental Drift. Iceland is well situated to test the theory. The position of certain points should be determined with great accuracy, so that after a lapse of years even a few yards' shift could be detected. German scientists had begun on this project before the War, and had set up a number of triangulation points in Iceland. However, the Icelanders were so suspicious that these might be camouflage for some military project, that they destroyed them all: another of the innumerable minor tragedies of modern war!

But there are other faunas represented in Iceland. An important one is the North Atlantic fauna, mainly of course of marine creatures, but emerging into the air in the form of a number of sea-birds which exist on both east and west coasts of the North Atlantic, and on suitable islands in between. Gannets, guillemots, razorbills, and puffins are examples. This North Atlantic bird fauna seems to have differentiated comparatively recently—perhaps as a result of the drifting apart of Northern America and Northern Europe—and consists of immigrant types from other regions—from the Arctic, from the Pacific round Cape Horn, and from the Indian Ocean.

Finally—believe it or not!—the Antarctic fauna is represented in Iceland. The Bonxie or Great Skua is merely a subspecies of a dominant species widespread in the antarctic and subantarctic regions. Many high latitude birds migrate to the other hemisphere after breeding, thus perpetually avoiding winter. Our bonxies must be descended from some southern-hemisphere migrants which stayed to breed in their off-season area—one cannot say "in their winter quarters".

Thus we have in this one island representatives of five faunas—North Hemisphere Old World, North Hemisphere New World, North Atlantic, circumpolar South Hemisphere, and circumpolar North Hemisphere.

This last includes two subdivisions—the true Arctic fauna, with such Iceland birds as little auk and glaucous gull, and the subarctic and north-temperate forms shared by New and Old Worlds, such as wheatear, raven, mallard, and slavonian grebe.

One of the interesting things that came to our attention was the frequent distinctiveness of the local Iceland race or subspecies of various species of birds. For instance the Iceland wren is both larger and darker than ours in Britain, and the Iceland redpoll is also larger than our British subspecies, the so-called lesser redpoll, as well as having a recognisably different call-note. The redpoll, by the way, is an example of an Iceland bird which is small in size but yet is found in Greenland and North America, as well as in the Old World, so that it, like the wheatear, is Holarctic. But, unlike the widely spreading ducks, both these small birds break up into numerous well-marked subspecies.

The wren is curious in this respect. Although it has produced separate and distinctive subspecies in Iceland, Faeroe, St. Kilda, and Shetland, it is uniform over the whole of western and central continental Europe. The separation of Britain from the continent has not resulted in the evolution of a British subspecies, though this has happened with many other birds, of which our pied wagtail, so easily distinguishable from the continental white wagtail, is an example. Why this is so, is a real puzzle.

I mentioned that the Iceland redpoll and wren were larger in size than ours. This is an example of an interesting general rule—that in general, warm-blooded animals are found to be slightly larger the nearer they live to the pole; further, in mammals, the *relative* size of ears, tail and limbs tends to diminish—a phenomenon strikingly illustrated by the tiny ears of the Arctic fox as compared with the huge flaps of the Fennec fox from the scorching deserts. These changes are undoubtedly adaptations, working to reduce heat-loss in cold climates and to promote it in over-hot ones.

Thus some of the special characters of Iceland birds are adaptations to climate while others, like the colour of the Iceland wren, seem to be more or less accidental results of isolation. But there is a third class of difference, and perhaps the most interesting—the differences in behaviour and song. Some of these differences, like the harsher song of the Iceland wren, are again aspects of the distinctiveness of the local subspecies. Others seem to be due to the birds being on the margin of their range, in surroundings quite different from the normal. Thus, as already mentioned, the Iceland wren out of the breeding season has to become almost exclusively a shore-bird.

Frequently, however, the reason is more subtle—the

absence of competition from close relatives which have not reached this part of the species' range. Thus in Britain, snipe are inhabitants of open country, so that it was surprising to find them quite common in the one of Iceland's two woods that we visited. James Fisher hit on what I am sure is the solution—namely that there are no woodcock in Iceland. With us, woodcock occupy the habitat provided by boggy woods. But where they are absent, the snipe avail themselves of this as well as of their normal open habitat.

But the absence of close relatives may have another effect. When two closely allied species come into contact in the same area, it is in general a biological advantage for them to proclaim their distinctiveness by some characteristic difference of plumage or voice. This will help to prevent actual or attempted cross-breeding, trespassing and other wastes of time and energy. In Britain, the closely related meadow and tree pipits are not only restricted to different habitats, but sing quite distinctive songs. With us, the meadow pipit is exclusively a bird of moors and heaths and other open country, and its song is a rather feeble descending scale gradually accelerated into a little trill, given as the bird parachutes down after having flown up from the ground. The tree pipit, on the other hand, demands scattered trees, and has a much more striking song; this is also given in the air while floating down, but the flight starts from (and often ends on) a tree perch.

Here the need for distinctiveness cannot well be met by colouration, since both species are adapted to concealment by cryptic colouration; but the songs, given high in the air, are obvious trade-marks for the two species.

In the Iceland birchwood where we found snipe, there were also meadow pipits. We would never have dreamt of finding meadow pipits in such a place in England, and their presence was clearly due to the absence of their close relative and competitor, the tree pipit. What is more, the song of one of them had a distinct tree pipit flavour, and it was begun from a tree perch.

Finnur Gudmunsson told us that in western Iceland he had once spent a couple of hours stalking the singer of a song which was wholly unknown to him: he eventually shot it for identification purposes—only to discover that it was an ordinary meadow pipit! This too, was in a birch area, though the birches here were only scrub. Thus the relaxation of the need for distinctiveness seems to have permitted the song to change.

The meadow pipits of open country in Iceland have so far not been heard to give any intermediate or markedly abnormal song (though one we heard in the Westmann Islands was exceptional for its brilliance): possibly the woodland and scrubland birds are evolving into a distinct ecological race.

There remains to mention one amusing incident. In this same wood, we found a redwing's nest quite high in a birch tree. Now in Iceland the redwing, that attractive little thrush, is normally a confirmed ground-nester, though in Norway it frequently builds in trees, and Dr. Gudmunsson was quite impressed by this unusual event. Then on Myvatn we saw another tree-nest, some 8 ft. up in a willow; and Dr. Gudmunsson grew really excited—until Sigfinnson, the farmer-naturalist, reminded him that this had been the latest season in living memory, and that the ground had been deep in snow when the breeding urge took the redwings. Seeing that they thus so readily revert to ancestral

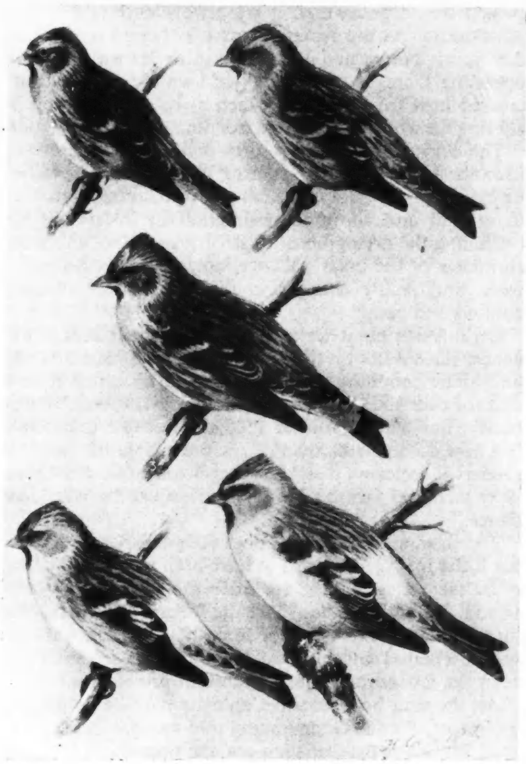


FIG. 5.—Five subspecies of two species of redpoll (*Carduelis flammea* and *C. hornemanni*), to show increase of size with colder climate of breeding area. 1. Lesser redpoll, *C. flammea cabaret* (Alps, Britain); 2. Mealy redpoll, *C. f. flammea* (circumpolar, exclusive of Greenland, from northern Norway and Sweden to Canada); 3. Greenland redpoll, *C. f. rostrata* (southern half of Greenland); 4. Cones' redpoll, *C. hornemanni exilipes* (circumpolar, exclusive of Greenland, but more northerly than mealy redpoll); 5. Hornemann's redpoll, *C. f. hornemanni* (Greenland, but more northerly than Greenland redpoll).

In *Carduelis flammea*, measurements show that wing-length increases by roughly 1% for each 2 degrees of N. latitude.

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habit under the stress of necessity, it is rather curious that they do not normally do so as a matter of convenience wherever trees or bushes abound.

Finally, I come to what to me is the most interesting point of all—the bearing of field natural history in Iceland upon the fascinating and basic question of a world-wide change of climate.

Professor Ahlmann, the well-known Swedish geographer, in a recent issue of the *Geographical Journal*, has summarised all the evidence on this subject. He concludes that in the northern hemisphere a widespread amelioration of climate is in progress, most marked in higher latitudes. It began about a hundred years ago, but has been especially marked in the last two decades. The most likely explanation

(which would be assured if we get evidence of a similar amelioration in the Antarctic, as it is hoped to do from the joint Norwegian–British–Swedish expedition now operating there) is that it is world-wide, and due to increased heat from the sun, which in its turn operates by altering the world's great system of atmospheric circulation.

The evidence is of every sort—increased temperatures, spectacular regression of glaciers, changes in the position of main low-pressure and high-pressure areas, alterations in rainfall and snowfall, desiccation in lower latitudes (including the drying up of East African lakes), enormous shrinkage of the polar pack-ice, enlarged growth-rings of trees, and finally changes in the distribution of many animals and plants.

On this last point Iceland provides a great deal of evidence, since it lies on the sensitive limit between subarctic and arctic conditions. We know from historical records that for over 400 years the early colonists successfully grew barley, but that soon after 1300 this became impossible. But now, to quote Ahlmann, "the present shrinkage of the glaciers is exposing districts which were cultivated by the early medieval farmers but were subsequently overridden by ice."

The ensuing cold spell of about 600 years has been called the Little Ice Age; it seems to have been the coldest period since the retreat of the ice after the last major glacial period. At any rate, about 1880 the Iceland glaciers reached their maximum extension for some 10,000 years, while the warmest period since the end of the Ice Age seems to have been the few centuries just before our present era.

As showing how sensitive animals may be as climatic indicators, Finnur Gudmunsson told me that in the warm spell just before the Christian era, the dog-whelk (*Purpura*) was found all along the north and easts coasts of Iceland, while today it stops dead at the N.W. and S.E. corners. (The slightly hardier whelk, *Buccinum*, still occurs all round the island).

To come down to the present, the last few decades have seen drastic changes in the fish which are Iceland's prime economic support. Herring, haddock, halibut, and especially cod have extended their range northwards in Greenland (the cod at the rate of about 24 miles a year for close on thirty years); and cod and herring are moving north from Iceland, so that anxiety is beginning to be felt about the future of the fisheries.

Meanwhile, there have been extraordinary changes in the bird population of the island. No less than six species—nearly 10% of the previous list of breeders—have only started to breed in Iceland during the present century. There is the tufted duck, which arrived in 1908, and has spread so fast that now it is the second commonest species on Myvatn; three gulls—the blackheaded, herring and lesser blackback; the coot and the starling, both only after 1940, the latter still confined to cliffs near its presumed landfall in the south-east.

Further, the oyster-catcher, previously confined to the south-west, has shown a spectacular spread northwards. The blacktailed godwit and the gannet have also pushed up the northern limit of their range, the latter having established three new colonies on the north and east coasts.

Meanwhile, the little auk, the only true high arctic species in Iceland, has entirely deserted one of its two breeding colonies in the north-east, and the other has dwindled to almost nothing; apparently Iceland is no longer cold enough for it. Finally, some plants are moving north—notably the bilberry (*Vaccinuim myrtillus*) which has colonised areas previously reserved to dwarf willows—and there have been similar shifts in some of Iceland's insects.

All these changes have become much more pronounced within the last ten to fifteen years.

We in Britain have had numerous examples of bird species spreading northward in the present century, including some birds which have been doing the same thing in Iceland, like the tufted duck, and others like the black redstart which are quite recent invaders of these islands.

All such observations take on new interest when it is realised that they can contribute to our understanding of a world-wide and secular change of immense significance for our human future; and one which is unique, since, in Ahlmann's words, "it is the first fluctuation in the endless series of past and future climatic variations in the history of the earth which we can measure, investigate, and possibly explain."

I have certainly returned from my Iceland trip with a new awareness of the importance (in addition to the interest) of field natural history.

Alphabetical list of birds mentioned in the text

Arctic Tern, *Sterna macrura.*

Blackheaded Gull, *Larus ridibundus.*
Blacktailed Godwit, *Limosa limosa.*
Black Redstart, *Phoenicurus ochrurus.*
Barrow's Goldeneye, *Bucephala islandica.*
Bonxie, *Stercorarius s. skua.*

Common Scoter, *Melanitta nigra.*
Coot, *Fulica atra.*
Cuckoo, *Cuculus canorus.*

Dipper, *Cinclus cinclus.*

Fieldfare, *Turdus pilaris.*
Fulmar Petrel, *Fulmarus glacialis.*

Gadwall, *Anas strepera.*
Gannet, *Sula bassana.*
Glaucous Gull, *Larus hyperboreus.*
Golden Plover, *Pluvialis apricarius.*
Great Northern Diver, *Colymbus immer.*
Great Skua, *Stercorarius s. skua.*
Greylag Goose, *Anser anser.*
Guillemot, *Uria aalge.*

Harlequin Duck, *Histrionicus histrionicus.*
Herring Gull, *Larus argentatus.*
House Sparrow, *Passer domestica.*

Iceland Redshank, *Tringa totanus robusta.*

Lapland Bunting, *Calcarius laponnicus.*
Lesser Blackback, *Larus fuscus.*
Lesser Redpoll, *Carduelis flammea cabaret.*
Little Auk, *Alle alle.*
Longtailed Duck, *Clangula hyemalis.*
Loon, *Colymbus immer.*

Mallard, *Anas platyrhynchus.*
Meadow Pipit, *Anthus pratensis.*

Old Squaw, *Clangula hyemalis.*
Oyster-catcher, *Haematopus ostralegus.*

Pied Wagtail, *Motacilla alba yarrellii.*
Pintail, *Anas acuta.*
Puffin, *Fratercula arctica.*

Raven, *Corvus corax.*
Razorbill, *Alca torda.*
Redpoll, *Carduelis flammea.*
Redshank, *Tringa totanus.*
Redwing, *Tordus musicus*
Ring Ouzel, *Turdus torquatus.*
Rock Dove, *Columba livia.*

Scoter Common, *Melanitta nigra.*
Shoveler, *Spatula clypeata.*
Slavonian Grebe, *Podiceps auritus.*
Snipe, *Capella gallinago.*
Starling, *Sturnus vulgaris.*
Swallow, *Hirundo rustica.*

Teal, *Anas crecca.*
Tree Pipit, *Anthus trivialis.*
Tufted Duck, *Anthya fuligula.*

Wheatear, *Oenanthe oenanthe.*
Whimbrel, *Numenius phaeopus.*
White Wagtail, *Motacilla a. alba.*
Whooper Swan, *Cygnus cygnus.*
Wigeon, *Anas penelope.*
Willow Warbler, *Phyllocopus trochilus.*
Woodcock, *Scolopax rusticola.*
Wren, *Troglodytes troglodytes.*

Model Experiments in Flood-Control

F. E. BRUCE, M.Sc., S.M., A.C.G.I.

ONE of the better-known characteristics of our American cousins is a propensity for doing things in a big way. In some respects we may be excused for envying them on this score. But bigger does not always mean better. When it comes to floods, for instance, we may well be thankful that we are not visited with such catastrophic deluges as those which periodically descend on the inhabitants of some of the great river valleys of the United States. These floods bring death to many, and loss and suffering to thousands, and cause millions of dollars' worth of damage every year.

By far the greater part of this loss occurs in the valleys of the Mississippi and its tributaries, including the Missouri and Ohio Rivers. This is not surprising when one considers that the watershed draining into the Mississippi covers 41% of the area of the United States—plus a little bit of Canada. It includes all or part of thirty-one states and has an area of 1,244,000 square miles, more than ten times the area of the British Isles.

The whole of the surface water draining from this area converges on the Lower Mississippi. A rainstorm in any part of the area will have its effect sooner or later on the flow of the main river, and if the storm is widespread many of the tributary streams may contribute their quota. Over such a wide area, there may be many storms going on at once. In spring, too, melting snow on the Rockies and elsewhere will add large volumes of water. The Lower Mississippi bears the brunt, and can scarcely be blamed if it occasionally decides to share its burden with the adjacent low-lying lands.

Naturally, attempts have been made since the early days of settlement to prevent this, and to impose some sort of control on the river. The obvious way to do this was to build high banks, or levees, along the river, and since the first works of this nature by French settlers in 1717, a great system of levees has been built up. But more extensive levees meant fewer opportunities for the river to overflow locally. The flow in the lower reaches, therefore, became faster and deeper, and the severity of flooding when the river overtopped or broke its banks was greatly increased. This has happened many times, and the levees have been constantly raised and strengthened in an effort to keep pace with the increased flood-levels of the river.

Scouring of the soft sand and silt of the river bed is another threat to the levees, for the river is continually changing the course of its giant meanders, eating away here, depositing silt there, so that the siting of levees is a matter calling for careful investigation, delicate judgment—and not a little luck.

The use of levees in flood-control work is at best a passive measure. The river is still the master, capable of foiling the best-laid plans by a combination of cunning and brute force. It must be dealt with by more positive measures. Society does not protect itself from dangerous criminals merely by locking its house doors and employing police to patrol the streets. It prefers to keep them locked up out of mischief.

So with the flood-waters of the Mississippi and its tributaries. They, too, must be locked up, and released only under conditions which ensure their good behaviour. This can be done by building dams at strategic points so that in times of storm the excess water can be impounded. The water can later be released at a rate which the river channel can safely carry without flooding.

The problem of locating these dams, especially on such a complicated system of rivers as the Mississippi Basin, is far from easy. They must be sited where they can give maximum benefit, not only to the river immediately downstream, but to the system as a whole. The ideal location from the operational point of view is, however, rarely the cheapest, and as in all large engineering projects, compromise is inevitable. Many of these dams serve also for power generation and to aid navigation, and the latter factor, in particular, has a very important bearing on the siting of a dam.

The total number of flood-control reservoirs existing, under construction or projected, within the Mississippi watershed, is about 200. Clearly, their operation must be co-ordinated over the whole area if storm waters are to be released safely and without risk of flooding. The development of a plan of operation for so many widely spaced reservoirs is a complicated problem, which is not amenable to mathematical analysis, owing to the large number of variable factors involved.

Construction of the Models

A big problem it may be, but no bigger than the American engineer relishes. With characteristic energy and sense of scale, the U.S. Waterways Experiment Station at Vicksburg, Mississippi, under the supervision of the President of the Mississippi River Commission, and working to the orders of the Chief of Engineers, U.S. Army, has been constructing, for the past five years, a vast scale model of the whole 1,244,000 square miles of the Mississippi watershed. The technique of using models for the study of hydraulic problems, such as the silting or scour of rivers, or the design of harbour or dam structures, has been developed to a high degree of reliability during the past seventy years, and, with proper care and skill, predictions of the behaviour of full-size streams or structures may safely be based on the results of model experiments. (See "Tidal Models" by A. W. Haslett, M.A., DISCOVERY, November 1948, p. 327.) The Mississippi Basin model is presumably (in default of any rival claim from Russia) the largest hydraulic model in the world at present. It is built to a horizontal scale of 1 : 2000 and a vertical scale of 1 : 100, giving a vertical exaggeration of 20 to 1. The dimensions of the model are thus about 4,500 ft. from west to east and 3,900 ft. from north to south, and the area covered is 200 acres. It would be a tight fit in Hyde Park!

All of the principal rivers in the basin, having a total length of 15,000 miles, are built into the model, the scale length being nearly 8 miles. The Lower Mississippi is represented by a channel 30 in. wide and from 6 to 18 in. deep. Although the site of the model was carefully chosen so as to minimise excavation, about a million cubic yards

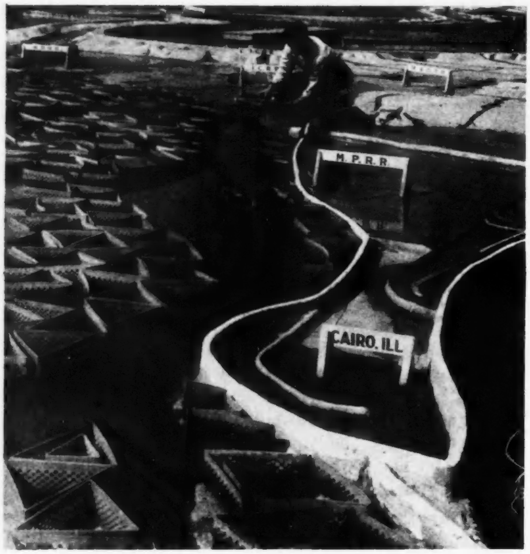


FIG. 3.—A model of the confluence of the Ohio and Mississippi Rivers at Cairo, Ill. The engineer is introducing red dye into the stream so that sub-surface currents may be studied.

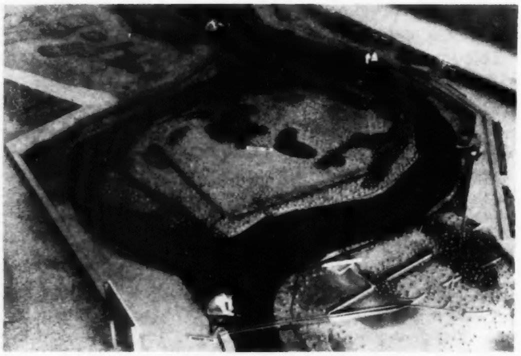


FIG. 2.—A model of the Mississippi at Memphis, Tenn. Point gauges are used to measure water levels. The tracks of floating powder or other material indicate the directions and speeds of surface currents.

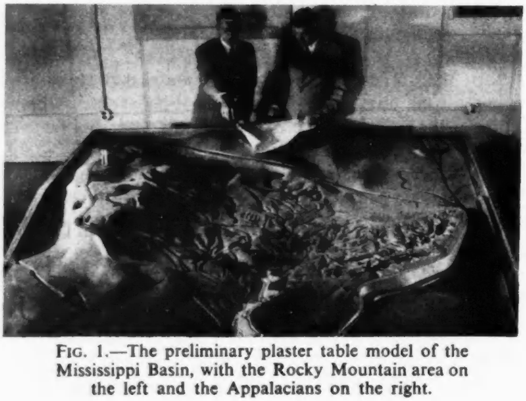


FIG. 1.—The preliminary plaster table model of the Mississippi Basin, with the Rocky Mountain area on the left and the Appalacians on the right.

FIG. 4.—Model of the outlet works, Denison Dam, Texas. Scale 1 : 80. The water is discharged into the stilling basin on the right. The three outlets in the centre are for future extensions to the power-house.

of 'muck-shifting' was necessary to bring all parts of the model to elevations corresponding to those in the original. A good idea of the general shape and relief is given by Fig. 1, which shows a preliminary plaster table model.

After the general shaping of the valleys and hills, the principal valley floors were moulded in concrete, and the intervening ridges covered with turf. This work is seen in progress in Fig. 8, which gives some idea of the intricacy of the concrete-moulding work involved.

All of the 200 or so existing or proposed flood-control reservoirs will be represented, as well as all levees, floodways, and other works which might affect the flow of the rivers. In operation, storm flows of known magnitude, based on past records, will be introduced into the appropriate rivers, and the resulting rise and fall in water-levels at various points throughout the model will be recorded by sensitive electrical gauges. There will be about 1,500 of these and the task of correlating the results obtained from each set of test conditions will not be a light one. Experiments under many different conditions will be required before conclusions can be drawn as to the best locations and designs of flood-control structures and the most effective way of operating them. But the engineers are confident that all the work and expense involved in building and operating the model will be repaid many times over; and when one's annual budget runs to around $300,000,000, as in the case of flood-control works in the Mississippi Basin alone, there is plenty of scope for useful economies.

When completed, the giant model will be viewed from a road 3 miles long encircling it, with observation towers at suitable points. A visit to the model will undoubtedly be a fascinating and instructive experience for members of the public and their small boys.

This model is a natural development from smaller models which have previously been used by the Waterways Experiment Station. For instance, a model to the same scales, but representing only the lower 400 miles of the Mississippi, was built in 1938, and has been used in numerous studies to determine the effect of particular schemes of flood-control. This model is used to investigate the performance of the Morganza and West Atchafalaya floodways, which constitute a part-natural and part-artificial by-pass for floodwater. Screen wire is used in irregular patterns on the 'over-bank' areas to provide resistance to the flow of water comparable to that of the natural vegetation, buildings, and fences. The amount of 'roughness' to be provided has been determined by trial and error so that, under

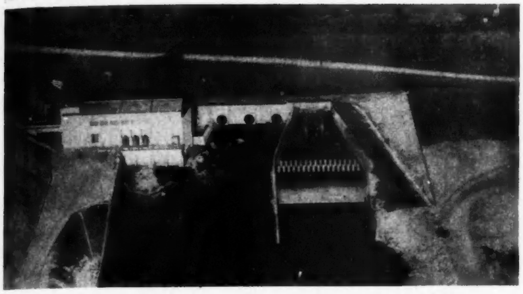


FIG. 5.—Aerial view of the outlet works, Denison Dam. The energy of the floodwater is dissipated in the stilling basin by impact with the two rows of obstacles which minimise scour downstream.

given conditions, water-levels and discharges correspond to those actually measured during past floods.

Another method of providing this roughness is seen in Fig. 3, where perforated plates in triangular formations break up the flow of the flood-waters. This model represents the confluence of the Ohio River (entering from the right) with the Upper Mississippi at Cairo, Illinois. The photograph also shows the stucco ribbing which provides the necessary friction in the bed of the Ohio. In Fig. 2 small boulders are used to give the required over-bank roughness.

The models we have been considering have all been primarily for the study of river flow, and have been constructed to comparatively small scales. When a structure like a dam is being designed, use is often made of a larger model built to a natural scale, i.e. with no vertical exaggeration. Fig. 6 shows a model of this type, representing the proposed Demopolis Dam, Alabama. This scheme is of unusual interest. The dam, which is designed to raise the level of a stretch of the Tombigbee River to assist navigation, will be provided at one end with the lock shown in the photograph. In times of flood, the water-level will rise as much as 9 ft. above the crest of the dam, and the lock will be flooded out and useless. Shipping will then pass directly over the main portion of the dam, and the model is being used to ensure that the velocity of flow at such times is low enough to allow safe navigation, and to check adverse currents near the lock entrances.

Fig. 7 shows another undistorted model used to study the effect of alterations made to an existing dam at Prattville, Alabama, to provide increased spillway capacity. As a contrast to the detailed construction of the Prattville Dam model, it is interesting to compare Figs. 4 and 5, showing respectively the model and full-size outlet works of Denison Dam, Texas. Here, only the stilling basin, which receives the flood-water released from the reservoir, was under investigation, and there was no need to incur the expense of building an accurate model of the whole dam.

These examples indicate a few of the many kinds of problem which face American engineers concerned with flood-control, and the methods by which they are being solved. The use of models for this work is saving the United States millions of dollars on construction programmes, ensuring the most efficient operation of the works constructed, and playing a major part in removing the constant threat of flooding which hangs over the heads of so many United States citizens.

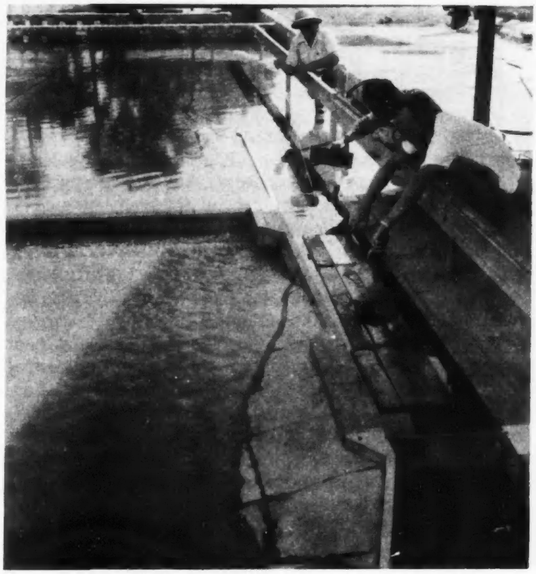


FIG. 6.—Model barges being towed through the lock of Demopolis Dam, Ala. Tests were made to study currents at the entrances to the lock.

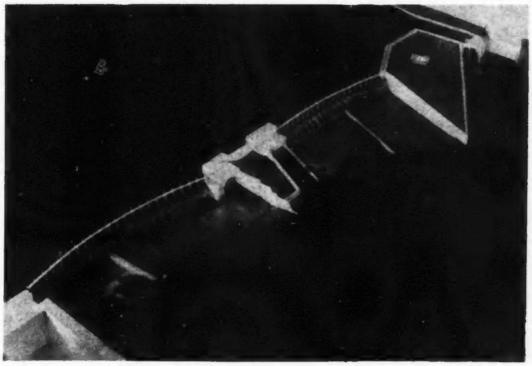


FIG. 7.—This 1 : 36 scale model of Prattville Dam, Ala., shows the amount of detail which is sometimes required to ensure hydraulic similarity with the prototype.

FIG. 8.—A length of the Missouri River modelled in concrete. The tents in the background protect newly laid concrete from the sun until it is hardened.

Quetelet: 'Galileo' of the Social Sciences?

E. M. FRIEDWALD

It is only rarely that a physical scientist has any useful contribution to make to the advance of social science. One would not expect a mathematician and astronomer, to succeed in becoming a pioneer in the study of society, and yet the Belgian, Quetelet, achieved just that. By any standard his career was a remarkable one; so that today this man who was a mathematician and astronomer, physicist and meteorologist, is chiefly known as a sociologist, particularly as the founder of social statistics.

Lambert-Adolphe-Jacques Quetelet was born at Ghent on February 22, 1796, the son of a minor municipal officer. While he was still in his childhood his father died, and the young boy had to earn his living as soon as he left secondary school. At seventeen he became teacher of mathematics—a subject in which he excelled—at a private school at Audenaerde, and a year later he was appointed professor of mathematics at the Royal College at Ghent. Here he met Jean-Guillaume Garnier, a distinguished French mathematician and astronomer, and this contact decided his future. For at that time Quetelet was strongly drawn towards literature and intended to become a writer. It was Garnier's influence that definitely deflected him towards a scientific career.

By the time he was twenty-three Quetelet was a professor at the Brussels Athenaeum. Soon afterwards, at about the same time, in 1823 to be exact, the decision was taken to build an observatory at Brussels, and Quetelet was sent to France to study the organisation and functioning of the Paris Observatory. He spent a few months there, and on his return to Brussels was put in charge of the construction of the new observatory. He became its director and held this office throughout his lifetime.

At about the same time he began giving popular lectures at the Brussels Museum on mathematics, physics, astronomy, and later in the history of the sciences. The lectures were published afterwards in book form, and these volumes enjoyed a very wide readership. Simultaneously he took on the editorship of *Correspondance mathématique et physique*, at that time the foremost publication of its kind in Europe, and in that capacity he came in touch with the leading scientists of the time, amongst them Herschel, Babbage, Ampère and Gauss.

All these teaching and administrative activities did not preclude Quetelet from carrying out original research in mathematics, astronomy and physics. In some ways perhaps his most interesting work in the field of natural science was done in meteorology, and he was responsible for organising extensive meteorological observations in Belgium and in other countries. One of the most important aspects of this work was his insistence on the necessity of simultaneous observations at different points—both in meteorology and astronomy—an idea which was new at the time. In 1839 he started regular observations of the effect of weather on vegetation, and so contributed to the foundation of phenology, which is the study of organisms in relation to climate.

If Quetelet's career had been confined to natural science, he would, by that alone, have secured a prominent place among nineteenth-century scientists. The Brussels Academy of Sciences early recognised his merits by electing him member at the age of twenty-four. Quetelet repaid the honour by invigorating the Academy with the new life it badly needed. He took an extremely active interest in its work, became perpetual secretary in 1834, and is considered the virtual creator of the Academy as it is today. Indeed, the Academy and the Observatory were two of the three main interests of his life. The third—for which he is chiefly remembered today—lay in his sociological and statistical studies.

The Sociologist and Statistician

It was no mere accident that a mathematician of the early nineteenth century should turn to the study of society. Indeed, it was because he was a mathematician and a physical scientist that he would do so. For this was the time when physical science was celebrating its greatest triumphs and when faith in the omnipotence of scientific method was at its highest, particularly in Paris, the Mecca of the greatest scientists of the period. The French mathematician and philosopher, Condorcet, had already voiced the opinion that the methods of the natural sciences were the only legitimate ones to apply to the treatment of social problems, particularly the methods of mathematics and the newly developed calculus of probabilities. He saw no reason why the intellectual and moral faculties of man, and historical development in general, should not be subject to general laws analogous to those which regulate physical phenomena. This line of thought permeated a whole generation of scientists, particularly the brilliant circle of professors and students revolving around the Ecole Polytechnique. Nothing perhaps better epitomises this spirit than Laplace's idea of a single world formula which would embrace the movements of the largest bodies of the universe as well as of the smallest atoms, and which would disclose the future as well as accounting for the past.

It was into that atmosphere that Quetelet found himself plunged when, at the end of 1823, he arrived in Paris to study the working of the Observatory. He spent only a few months there, but the influence under which he came during this short period was decisive in determining the direction and character of his thought. For he was instructed not only in astronomy by Arago but, far more important, in the calculus of probabilities by Laplace himself. And there is no doubt that this newly won knowledge, together with the philosophical views he imbibed from Laplace, Jean-Baptiste Fourier and other savants holding the same ideas, implanted in Quetelet's mind the germs of those thoughts which were afterwards to develop into his conception of the social system and the methods of investigating its laws.

It is certain that on his return to Belgium, Quetelet became more and more interested in social problems, especially social statistics, and the field they offered for the application of mathematics, more particularly the

calculus of probabilities. His early views on this subject were admirably stated in his opening lecture on the history of the sciences in 1826: "The more advanced sciences have become, the more they have tended to enter the domain of mathematics, which is a sort of centre towards which they converge. We can judge of the perfection to which a science has come by the facility, more or less great, with which it may be approached by calculation."

His *Instructions populaires sur le calcul des probabilités* (translated into English in 1839), bears on its title page the significant motto, "Numbers rule the world". The direction of his thought may be judged from this characteristic passage in the book "The theory of probabilities ought to serve as a basis for the study of all the sciences, and particularly of the sciences of observation. . . . Since absolute certainty is impossible, and we can speak only of the probability of the fulfilment of a scientific expectation, the study of this theory should be a part of every man's education. . . . Chance, that mysterious, much abused word, should be considered only a veil for our ignorance; it is a phantom which exercises the most absolute empire over the common mind accustomed to consider events only as isolated, but which is reduced to naught before the philosopher, whose eye embraces a long series of events and whose penetration is not led astray by variations that disappear when he gives himself sufficient perspective to seize the laws of nature."

The starting-point of his sociological studies was his investigation into the variation of physical qualities of man, in particular, of human statures. He observed that the curve representing this variation—known as the normal curve of distribution (or variation)—was, in fact, none other than that given by the theory of probabilities for the distribution of accidental errors. That is to say, the numbers representing the different statures are grouped round an average figure in exactly the same way in which single results of a given observation are grouped round the mean result, in accordance with the theory of probabilities. Much later, in his work on anthropometry, *L'Anthropométrie ou mesure des différentes facultés de l'homme* (1871), he laid great stress on the universal applicability of the binomial law, according to which the number of cases where, for instance, a certain height occurs among a large number of individuals is represented by an ordinate of a curve (the binomial) symmetrically situated with regard to the ordinate representing the mean result, i.e. the average height.

This statistical study of the physical qualities of man, Quetelet soon extended into the field of "moral statistics", which comprise the whole realm of human actions determined by moral and psychological factors. He started by studying crime statistics, and noted the astounding exactitude with which crimes are reproduced: "Thus we pass from one year to another with the sad perspective of seeing the same crimes reproduced in the same order and calling down the same punishments in the same proportion. Sad condition of humanity! . . . We might enumerate in advance how many individuals will stain their hands in the blood of their fellows, how many will be forgers, how many will be poisoners, almost as we can enumerate in advance the births and deaths that should occur. There is a budget which we pay with a terrifying regularity: it is that of prisons, chains and the scaffold."

Such was the celebrated conclusion which Quetelet drew from his first study of moral statistics which appeared in 1828. His conviction that there was a regularity in man's moral and intellectual development was further strengthened by the statistical study of the proportion of suicides, of the annual number and age distribution of marriages, the annual number of births, of duels, even of such imaginative faculties as dramatic talent. No doubt others had studied birth and marriage statistics, but Quetelet was the first to perceive in such studies a field that could be expanded to include the whole nature of man and the characteristics of human society. The regularities he elevated to the rank of social laws, comparable to and as rigorous, thought Quetelet, as the laws of physics. The simple proposition that the moral nature of man and the qualities of a group of men can be studied by a statistical investigation of their actions was exalted by him into the foundation of an exact social science.

The Average Man

Already the study of human statures had led Quetelet to conceive society as a body having at its centre of gravity, "the average man", a concept he first presented in 1831. He considered the differences between this basic type and the various individuals as so many accidental errors made in the multiple reproduction of the type, in accordance with the theory of probabilities. This concept he soon extended to man as a moral and intellectual being: "That which relates to the human species considered *en masse* is of the order of physical facts; the greater the number of individuals, the more the individual will be effaced" in favour of "the series of general facts which depend on the general causes, in accordance with which society exists and maintains itself. These are the causes we seek to ascertain, and when we shall know them, we shall determine effects for society as we determine effects by causes in the physical sciences." As expounded in his *Du système social et des lois qui le régissent*, published in 1848, "the average man" was extended as a means of interpreting social phenomena either statically or dynamically, both from a national and a world standpoint.

Quetelet's views exercised a strong influence, and greatly helped to spread the idea of determinism in social phenomena, though he himself was not always very clear and consistent about the degree of this determinism. At times his writings express the conviction that there actually exist in nature fixed types which are preserved despite differences in climate, environment, habits and institutions. But he generally recognised that the averages were dependent on social conditions, and that man can, by his own exertions, change these conditions, though only very slowly; in other words, the averages vary with time and space. These variations made possible the study of causal relations in social phenomena, for a change in social conditions would produce a change in the averages. In fact, he made the fundamental aim of the science of statistics the study of the co-existence and sequence of social phenomena in correlation with the environing conditions of social life. This was the object of social physics —to uncover the natural laws which rule social life. It was also the subject of his *magnum opus*, *Physique sociale*,

ou essai sur le développement des facultés de l'homme, first published in 1835.

The concept of the average man was the one principle that unified all Quetelet's work on population, statistics, anthropology and sociology. Whatever its failings as a theoretical doctrine, it was of great practical significance for the perfecting of statistical method and for the development of biological science. For the concept was extended by Quetelet to animals and plants, and thus made possible the quantitative study of biological variation. Actually Quetelet came very close to the discovery of the selective action of the environment—in his proposition that the average conforms to the necessities of time and place. But though he developed and used the method which later served in the works of Galton, Pearson and others as the basis of mathematical demonstration of evolution, he himself never used it for this purpose.

But apart from being the precursor of studies of biological variation, Quetelet's work also opened the way for the study of experimental psychology and for the inductive study of social life in general. He conceived a most extensive and important rôle for the average man. By making use of this concept, the politician, for instance, could more accurately play upon the general sentiments and beliefs which make up public opinion; the sociologist would be able to ascertain, both for nations and individuals, their laws of birth, growth and decay, of equilibrium and motion, and could thus uncover the true mechanism of human history. It is not difficult to see why Quetelet's average man fascinated historians, politicians and sociologists alike. Buckle found in Quetelet's work a statistical basis for some of the generalisations in his *History of Civilisation in England*; and Graham Wallas, in his famous study on *Human Nature in Politics* (first published in 1908 and reprinted in 1949), laid great stress upon the possibility of increasing the efficiency of political science, that is, its accuracy in forecasting the results of political causes, as a result of the increasing tendency of political thinkers to use, under the influence and example of the natural sciences, quantitative rather than merely qualitative methods—the methods which Quetelet was the first to devise and promote.

But Quetelet's influence on the development of statistics came as much from his purely practical work and from his activity in promoting work on an international plane as from his more academic work. In 1826, upon the formation of the statistical bureau of Holland (Belgium was then part of Holland), he contributed to the formulation of the plans for the census of 1829. In 1827 and 1828 he travelled widely, gathering together an incredible amount of statistical information, which he classified with great care and method. This information, which was later supplemented by facts and figures sent to him by statisticians from all over the world, formed the basis of his studies. After the revolution of 1830 he became supervisor of statistics in the Belgian administration, and it was largely thanks to him that, in 1841, the *Commission Centrale de Statistique* was organised. He became its president and held this office throughout his life. It was in this capacity that he made his most important contributions to the practical methods of statistical work. The practical rules developed by him for census taking still form the basis of modern census work.

Curiously enough it was he who suggested to Babbage the creation of the Statistical Society, which was formed in London in 1834. He was extremely active in promoting international co-operation in statistics, and put forward this idea at the London Exposition in 1851. The result was the first International Congress of Statistics, held in his honour at Brussels in 1853; seven such congresses were held during his lifetime, and he was the moving spirit, as well as the president, of all of them. International statistics will for ever remain his most splendid creation. He was extremely active in this field until the last days of his life.

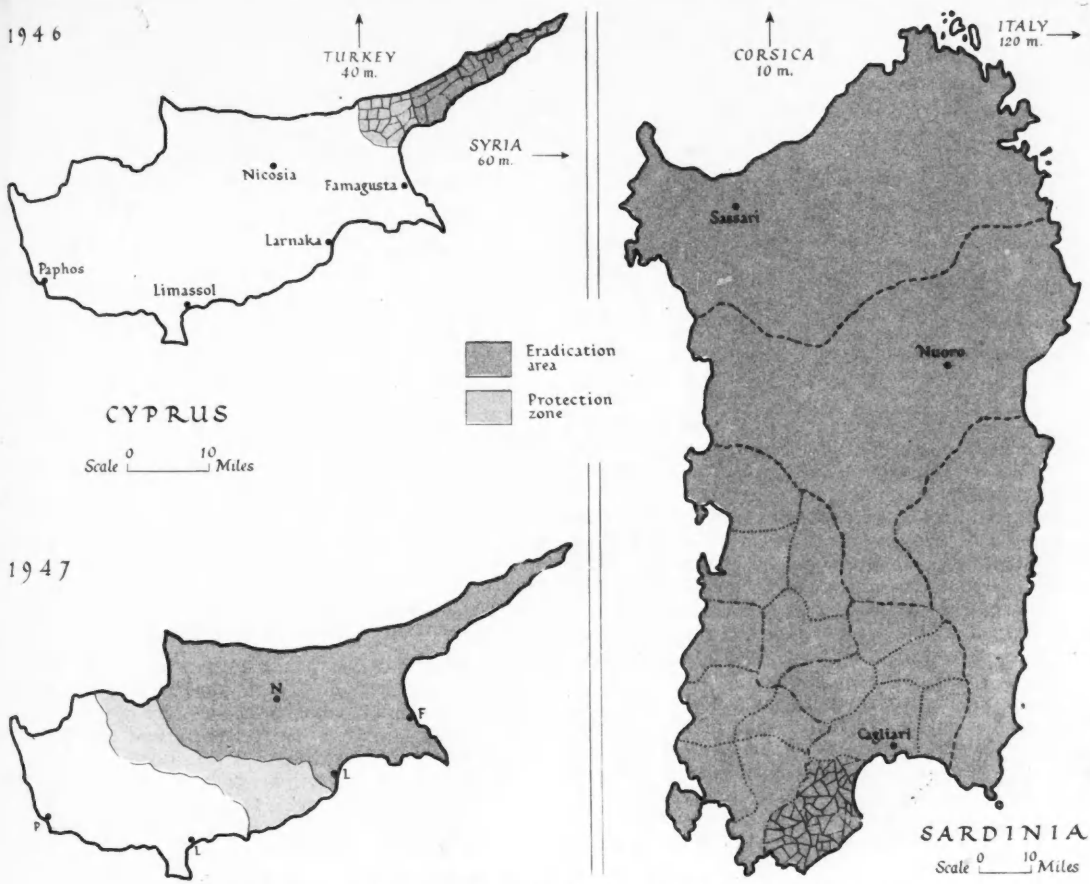
He died in Brussels at the age of seventy-eight, on February 17, 1874, at the very height of his fame, mourned by many as the founder of a new science.

Exaggerated as this claim may appear today, the fact remains that Quetelet, as the pioneer of moral statistics, first formulated and applied the quantitative method of research, essential to the development of the social sciences. Should the study of society ever approximate the exactness of the physical sciences, Quetelet may then appear as the Galileo of the social sciences.

PROGRESS OF SCIENCE—*continued from p. 72*

made in segregating the more routine tests, those for glassware, thermometers, barometers, and so on being already grouped together in the old glass-testing building; many routine tests from the different divisions will eventually be carried out by this separate section, the officers of which are in constant liaison with the appropriate divisions.

Since the foundation of the N.P.L., slight changes in the emphasis in certain aspects of the work there have been noticed. In the very beginning, associated with the pressing work of testing and standardising, there was a certain amount of fundamental research. Some of the tests, as already stated above, have become routines, and many of the standards are firmly established, not, of course, with absolute finality, but with sufficient stability to justify the devotion of more time to research. Today about half the activity of the N.P.L. is such research. It derives in the first place from the needs of tests and standards; so it is practical research. At the same time the liaison between the N.P.L. and government departments and committees with national status has gone on progressively. For example, the Aeronautical Research Council after the war recommended that the Aerodynamics Division of the N.P.L. should continue "to engage on research of a fundamental character". Another example: the British Electricity Authority sent the problem of smoke-dispersal in connection with new generating stations to the N.P.L. for investigation. The result of all this fundamental research and the liaison with public bodies is that papers and communications from workers at the N.P.L. appear not only in its collected researches and reports but in the proceedings and journals of various learned societies, and the N.P.L. has something of the character of a general physical research laboratory as envisaged by Sir Oliver Lodge when in 1891 he appealed for the setting up of a national physical laboratory.



(Left): *Cyprus*: Two stages in the eradication scheme. The 1946 map shows the Karpas peninsula divided into treatment blocks. (Right): *Sardinia*: Four main regions are shown. The south-west region is shown divided into its divisions and sections, and one section is divided into treatment blocks.

Eradicating the Mosquito

J. R. BUSVINE, D.Sc.

MALARIA is commonly thought of as a disease of swampy places; but, oddly enough, many malarial regions are exceedingly arid, for several dangerous species of mosquito will breed in very small accumulations of water. A stopped-up gutter, rainwater in an old tobacco tin, coconut shell or hoof-print may serve as a breeding-place for some varieties; others may be found, as larvae, in tiny trickles and seepages. In a mosquito eradication campaign, every single breeding-place must be discovered and treated regularly, for a considerable period, throughout an area of perhaps several thousand square miles. This is a very bold undertaking, and perhaps something should be said of the events which led up to the first attempt.

Mosquitoes being so numerous, prolific and minute, entomologists have seldom considered the feasibility of their total eradication from any large area. As with other insect pests, we have come to be satisfied with repeated 'control measures'. Satisfactory 'control' of mosquitoes implies that their numbers are kept low enough (perhaps only near human dwellings) to prevent any serious risk of disease transmission. This widely accepted view formed the general policy of the Rockefeller Health Division doctors attacking yellow fever in Brazil in the 1920's.

Yellow fever was known as a disease carried from man to man by the house-haunting mosquito *Aëdes aegypti*. This mosquito was not difficult to control, and reasonably well organised measures were found adequate to suppress the disease. Since it was then believed that yellow fever was an exclusively human disease, it seemed reasonable to suppose that, if transmission was stopped for a few years, it would die out altogether. Therefore, after what seemed a safe period, *Aëdes aegypti* control was stopped. Unfortunately, as we have subsequently learnt, yellow fever virus exists in forest animals, such as monkeys. Intermittent human cases occurred in rural areas and eventually the

TABLE I
APPROXIMATE STATISTICS COMPARING ANOPHELINE ERADICATION CAMPAIGNS

Country	*Main Anopheline Species concerned*	*Area involved (sq. mls.)*	*Maximum No. of Men*	*Time occupied (years)*	*Cost* (£1000s)
Brazil	*gambiae*	?	2,000	3	530
Upper Egypt	*gambiae*	1,500	4,000	2	800
Cyprus	*superpictus* (*bifurcatus*) (*saccharovi*)	3,600	700	3	300
Sardinia	*labranchiae* (*bifurcatus*) (*algeriensis*)	9,200	30,000 (6,000 larviciders)	3	3,000

disease was brought back to the large Brazilian cities, now fully infested with *Aëdes aegypti*. The result was a series of severe epidemics.

Thus, the Rockefeller doctors were brought to realise that the only safe way of permanently excluding yellow fever was the extermination of the man-to-man carrier *Aëdes aegypti*. A campaign was planned in great detail and directed with energy by an organisation headed by Drs. F. L. Soper and Bruce Wilson, and after a few years, the cities were cleared of *Aëdes*. A sentinel service remained to prevent its reintroduction.

The next example of eradication of a mosquito followed the introduction into Brazil (by ship) of the dangerous African malaria vector, *Anopheles gambiae*. Arriving about 1930, the insect found the climate suitable and spread rapidly. Finally, in 1938, a widespread malaria epidemic occurred which resulted in many fatalities.

This challenge could not be ignored by the men who had recently completed the *Aëdes* eradication campaign. It was decided to attempt the eradication of *Anopheles gambiae*. An organisation for the purpose was formed by the Rockefeller doctors with the Brazilian Health Authorities and the mosquito was attacked throughout the country from 1938 to 1940 with ultimate success.

A third undertaking of this kind concerned the eradication of *Anopheles gambiae* from Upper Egypt. The normal range of this mosquito does not extend beyond the Sudan; but in 1942 it extended northward along a 500-mile stretch of the upper Nile. There followed a severe malaria epidemic of some 200,000 cases and about 10% deaths. Following the examples in Brazil, an Eradication Service to attack *A. gambiae* was formed by the Egyptian Government and the work was directed by Dr. Kerr of the Rockefeller Health Division. The campaign lasted from 1944 to 1945 and succeeded in eliminating the intruding mosquito. In view of what will be said later, it should be noted that other, locally indigenous, mosquitoes were not exterminated.

The experience gained in these early eradication campaigns perfected an organisation which serves as a model for subsequent operations of this kind. The following are its fundamental points:

1. A preliminary survey of the territory must be made by an entomological team with considerable experience of anti-malarial work. Large-scale maps must be available.
2. The main attack is made on the larval stage of the mosquito. Every single breeding-site must be discovered, recorded and treated periodically throughout the breeding season. To do this, large numbers of workmen are required; they are recruited locally and may be of doubtful reliability. Therefore each man is made responsible for a definite limited zone. The zones are grouped into sections, the sections into districts, districts into regions and so on: these areas are in the charge of a hierarchy of responsible 'officers'.
3. A most important part of the campaign is to check the work and the checking service may absorb 25% to 30% of the budget. The checkers are of two kinds; larval scouts, who search the breeding-places for undestroyed larvae, and adult scouts, who search for adult mosquitoes. Larvae or adults collected are sent to regional laboratories for identification.
4. The whole undertaking must be systematised by printing large numbers of forms for recording instructions, treatment and the results of the checkers. The progress of the work is followed with the intensity of a military campaign. Disciplinary action is taken against men responsible for areas where repeated failures are reported by the checking staff.

Great credit is due to those responsible for the direction of those earlier eradication programmes. Their work has encouraged an even more ambitious type of project. The three campaigns which have been described attacked mosquitoes which breed close to human dwellings. Furthermore, it will be noted that *Anopheles gambiae* was breeding outside its normal range. Finally, all three campaigns followed severe epidemics of mosquito-borne diseases, which impressed all grades of public opinion with the value of such work.

The two latest campaigns (which I have witnessed in progress) have been undertaken in the Mediterranean islands of Cyprus and Sardinia. They were more ambitious in attacking indigenous mosquitoes which bred all over difficult territory, including places remote from human dwellings; they were undertaken as general measures of improvement without any special epidemic of malaria to act as a stimulus. To offset these difficulties, there has been the introduction of powerful new insecticides, such as DDT.

Cyprus and Sardinia are fairly typical Mediterranean islands. Cyprus is slightly smaller than Cornwall and Devon combined; Sardinia is rather larger than Wales. Both islands have considerable mountainous areas, the highest peaks of which rise above 6000 ft. The Mediterranean climate is well known to be hot and dry in summer (averaging 80° F.) and mild and wet in winter (averaging 50° F.). Of the 15 to 20 in. of rain per year, about half falls in the three winter months; the rainfall is only ½ to 2 in. in the three mid-summer months. Malaria has long been endemic in both islands; each year there were one to ten new cases and twenty to fifty relapses per 1000 population. Chronic malaria was widespread among many who did not actually qualify as 'malaria cases', and this general ill health depressed the standards of life.

In both islands malaria is seasonal, following the early summer abundance of the vector mosquitoes. The breeding

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FIG. 1.—*Sardinia*: One of the large labour gangs employed for clearing breeding-sites.
Photo: W. Suschitzky.

FIG. 2.—*Cyprus*: Men spraying breeding foci with DDT. At midsummer this marsh dries up into small isolated pools.

FIG. 3.—*Cyprus*: Spraying DDT larvicide on to small pools in a nearly dry river bed.

FIG. 4.—*Cyprus*: A typical breeding-place for *Anopheles superpictus*.

FIG. 5.—*Sardinia*: An entomologist examines a breeding-site on the edge of a rice field.

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of the mosquitoes is checked in winter by cold and in late summer by drought and absence of water for breeding sites. The principal malaria vector in Cyprus is *Anopheles superpictus* and in Sardinia *Anopheles labranchiae*. Both species (which are responsible for about 95% of the trouble) prefer warm, shallow, sunlit streams, pools and seepages for breeding. There are other malaria vectors in both regions, for example *Anopheles bifurcatus* which likes shady or cooler water to breed in; but these other species are relatively unimportant.

The operations in Cyprus were initiated by a former Director of Medical Services, Dr. Cheverton and later supported by Dr. Shelley (who succeeded to the directorship). The work was directed by the Chief Health Officer Mr. Mehmed Aziz. Funds were raised by the Cyprus Government and augmented by grants from the Colonial Development Fund.

The programme was as follows: in 1946, the Karpas peninsula (800 square miles) was attacked and this 'eradication area' was guarded by a 'protection zone' treated likewise. In 1947, half the remainder of the island was treated (2000 square miles) and in 1948, the final portion (1100 square miles) was covered.

The general organisation was similar to that adopted in the earlier campaigns. The larvae were attacked by spraying all breeding-places once a week with a 3–4% solution of DDT in crude kerosene. Various simple hand-operated atomising guns were used. Treatment consisted of a puff or two of spray per square yard of water surface. Before the introduction of DDT, a heavy dose of larvae-killing oil was required, perhaps 20 gallons per acre, applied by knapsack sprayer. The use of a DDT solution is effective at ½ gallon per acre, and this means that a man can easily carry supplies for a day's work (3–9 litres of solution and a hand sprayer).

During the summer of 1948, the period of maximum activity, about 600 labourers were employed on spraying duties. The average size of the plot for which each man was responsible was 5 square miles, one-sixth to be treated each working day. At this time there were about 180 larva checkers, making 120 to 200 thousand examinations per week.

The larvicidal treatments proceeded throughout the summer months. During the intervening winters, the operators made a careful search of all houses, animal shelters, caves and other natural harbourages in which the adult mosquitoes might be hibernating. These shelters were sprayed with a pyrethrum mist to destroy the resting insects.

The eradication work of Sardinia was initiated by Rockefeller experts who remained to direct the campaign. The director was first Dr. Kerr and later Dr. Logan, assisted by a Headquarters staff of British, American and Italian scientists and administrators. Money and supplies were made available from UNRRA and from the Italian E.R.P. fund. The plan of campaign differed somewhat from the Cyprus venture. An entomological survey of the island was made in 1946. In 1947, a trial of the larvicidal method and organisation was made on a district in the south-west (about one-fifth the area of the island). The all-out attack on larvae was made all over the island in 1948. The amount of work done was enormous. Some 3000 to 6000 men were employed to destroy larvae throughout the season and 500 to 1000 scouts were engaged in checking their work—this involved 300 to 500 thousand examinations per week. In addition a large number of men were employed in draining swamps and cutting away undergrowth; the maximum number put on this work in one week was 22,000, but the average number during the summer was nearer 10,000.

In the winters of the years 1946–8 a widespread attack was made on hibernating adults. Instead of the pyrethrum spray, which was used in Cyprus, a heavy residual spray of DDT was given to practically every house and shelter on the island. The DDT was transported as emulsion concentrate, diluted with water on the spot and applied with knapsack sprayers.

The two undertakings have a number of features in common. The territories are rather similar, the malaria is of the same type and the mosquitoes have, roughly, the same habits. In general, similar organisations were developed and similar methods of control were employed. Both teams met similar difficulties in the form of abnormal weather at times and resistance from certain inhabitants: for instance shepherds in Sardinia complained that DDT contaminated the drinking water or poisoned the sheep. Peasants in Cyprus complained that their silkworms had been killed and game poisoned.

The main differences were :

(*a*) the piecemeal programme in Cyprus as opposed to the all-out, one-year effort in Sardinia;

(*b*) the much bigger budget in Sardinia (See Table I).

This was expended partly on better transport (jeeps and trucks), on aircraft for spraying marshes and on special propaganda, but mainly on the extra labour force required for clearing and draining. These operations were undertaken to gain access to difficult breeding-grounds (which were not present to the same degree in Cyprus) such as streams overgrown by brambles and extensive marshes. These sites, which had defied treatment even by spraying from aeroplanes, harboured mainly mosquitoes of minor importance carrying malaria, but it would be difficult to guarantee that the main vector was eliminated if these breeding-areas were allowed to remain untreated.

I spent a month in Sardinia in July 1947 *before* the main larval attack had begun. At that time, one could pick a typical breeding-pool, dip into it and collect dozens of anopheline larvae. In July 1948 I spent a month in Cyprus wandering in remote districts *after* the larval 'blitz' had passed by. I did not find a solitary anopheline in the month of searching. These findings of a single observer do not mean much, but of the 740,000 examinations by the checkers, only 0·0069 % were positive. The reduction in numbers in both countries is clearly above 99·9%. But this is short of complete eradication and in both islands there have been sporadic discoveries of the main vectors throughout the summer of 1949 by which time the work should have been complete. Perhaps the final success may come after a few years of watching, if any foci discovered are attacked immediately. In any case, these great undertakings are of value as major experiments in applied biology. Another result, which should not be forgotten, is the steep decline in malaria incidence in both islands, far beyond the reduction due to ordinary control measures.

An Electro-mechanical 'Animal'

W. GREY WALTER, M.A., Sc.D.

For most people there is a smooth gradation between the obviously living 'self' and the obviously dead formless objects of nature; between these extremes are the constellations and mountains, seas and winds, trees and animals, statues and pictures, with all the ghosts and fairies, gods and devils circulating between. Until the scientific era the vitality accorded to an object was a function primarily of its form. Even ships, which of all machines are the most wilful and exacting, were not fully alive until they had been given a dragon's beak or a figurehead or formally christened and blessed. This preoccupation with objects which looked alive but had no life is not surprising, for we must remember that until a few generations ago there were no machines which did not depend on some already animated natural force—wind or fire or water. The technical genius of the Swiss watchmakers created a number of delightful clockwork automata but these aroused only passing interest because it was obvious that, intricate though they might be, they would only perform repeatedly a series of motions planned by the designer to mimic for example those of a boy writing a letter or a girl playing a guitar—their behaviour was determined and predictable—they were toys rather than totems.

When the power of steam, and later of electricity became commonplace in the last century, a new sort of machine became necessary, not as a totem or a toy, but as a tool—a machine which would control by itself the vast energy which could now be harnessed. If a steam engine is left to itself it will become unstable, since the boiler pressure will rise when the engine is off and fall when it is on. It is possible to employ a man as a 'governor' to maintain a constant pressure by alternately stoking and opening a release valve, but such a man would have to be paid very highly for such a responsible job, and quite early in the history of steam, Watt introduced the safety valve and automatic governor which could stabilise by themselves both boiler pressure and engine speed at any desired level. These two important devices were taken rather as a matter of course but the great Clerk Maxwell devoted a paper to the analysis of Watt's governor. Maxwell was perhaps the first to realise the significance of a mechanism which could control and stabilise a variable by a process of *feedback* between the output and input of a power generator.

With the invention of the thermionic vacuum tube just before World War I the era of electronics began and within a few years the need for auto-regulating devices of many sorts became urgent. In the quite early days of radio the automatic volume-control circuit was introduced to ensure that the output stages and loudspeakers were not overloaded by signals from nearby stations and to reduce the background noise when reception conditions were good. It is significant that the type of tube which provides this feature with its so-called variable 'μ' characteristic was originally regarded as an unsatisfactory design, due to bad grid-winding. Very frequently in the development of such schemes one finds that what had been regarded as shortcomings in the search for perfection turn out to have indispensable properties. The automatic volume-control circuit uses the same principle as the steam governor; a proportion of the output signal is fed back into an earlier stage of the radio amplifier in such a sense that if the output signal tends to get larger the amplification is automatically reduced and the volume of sound is maintained within certain limits.

A system of this type is usually described as having 'negative or inverse feedback', sometimes as 'degenerative' as opposed to regenerative. Theoretical analysis of this principle has intrigued many engineers, physicists and mathematicians; a stimulating approach is that of Prof. N. Wiener of the Massachusetts Institute of Technology, in his recent book *Cybernetics* (London, Chapman & Hall, 1949). The most important point about negative feedback from the human angle is that a closely analogous process underlies the physiology of the nervous system. Indeed long before negative feedback was understood by engineers, physiologists had described in detail how the sense organs, nerves and muscles of the body were organised in reflex circuits so as to maintain stability of the whole organism. Dynamic stability due to negative feedback is such an important property of animals and elaborate machinery that it is worth further consideration.

One can conveniently distinguish *internal* stability and *external* stability. The former, in the case of animals, is sometimes called 'homeostasis', meaning literally 'staying about the same'. In the evolution of animals one sees a steady trend toward mechanisms which maintain constant such internal variables as body temperature, the concentration of sugar and carbon dioxide in the blood, and all the elaborate physico-chemical relations which maintain life. Nearly all such mechanisms work through the nervous system. For example a small region at the base of the brain in ourselves acts as a thermostat. It sends signals to the sweat glands when the blood gets too hot and the skin is then cooled by evaporation. Dynamic control of temperature by this sort of retro-action is very efficient and is quite different from the control one can get by mere insulation with thick fur, just as a thermostat gas oven is different from a haybox cooker. Above all, control of the internal environment permits an animal to survive external changes which would otherwise destroy it—in Claude Bernard's immortal phrase—*La fixité du milieu intérieur est la condition de la vie libre.*

Animals usually have several methods of dealing with practical difficulties—if one fails or is inadequate another is used. In the human species, internal stability is achieved by modifying the external environment as well as by controlling the internal one. Unlike most animals, we are not satisfied with homeostasis; we *could* keep warm by shivering or by sleeping in a warm nest during cold weather but we find shivering uncomfortable and prefer more elaborate modes of activity. A condition in which our homeostatic mechanisms are lightly stressed we call comfort; a state of external stability, security. Analysis of the mechanisms underlying external stability involves study of animal behaviour, that is, psychology and sociology, ecology and economics, sciences which are still in the callow stage of speculation and dispute. Their backwardness

is probably due to the inherent difficulty of problems involving the stability of systems with large numbers of variables—physiologists try to simplify their experiments by anaesthesia and dissection, but in studying the brain they have been greatly assisted recently by methods originally developed for designing stable electrical transmission and control systems. These same methods may before long be used also to accelerate progress in social science, for they are essentially mathematical and therefore adapted for any subject, whether it deals with radar signals, nerve impulses, or parliamentary elections.

The convergence of electronic devices and animal physiology was becoming familiar just before World War II, but until the intricate circuit design and miniature components essential for radar became generally available, the possibility of constructing practical models of animal mechanisms seemed rather remote. At about the same time it was becoming increasingly obvious to brain physiologists that many if not all of the functions of the brain are carried on by electric signalling. Study of such activity is called electro-encephalography and is in general use for investigating the brain in health and disease. Results obtained during the last few years suggest that the nervous mechanisms underlying even such elaborate functions as original thought and imagination may some day be definable in electric terms. The serious possibility of real self-knowledge that this implies has stimulated efforts to mimic certain aspects of brain function by means of electro-mechanical devices in order to discover how far the neuro-electronic analogy can be pushed. (Experiments of this sort should be carefully distinguished from the construction of what are sometimes called 'electronic brains'; computing machinery designed to accelerate tedious mathematical calculations. Instruments of this latter type are designed to supplement, perhaps even in some respects to supplant the human brain and though they resemble the natural product in certain features, the similarities are of only general interest; the less a computing machine resembles a brain—particularly in its faults—the happier its designer will be.)

Two of the fundamental problems presented to neurophysiologists are:

1. On the psychological side, there is the subjective impression of the human that he possesses some degree of free will, and the objective fact that the analysis of human behaviour seems intractable by quantitative procedures.

2. From the physiological standpoint the brain contains about 10,000,000,000 individual nerve cells, the permutations of whose interconnections provide a quite unimaginably vast number of possible behaviour-patterns. If the scale of the problem is really so vast, then even the most refined techniques of study seem unlikely to yield conclusive results.

Is the complexity and unpredictability of behaviour correlated only with the size of the nervous system or is there some more mysterious factor? In order to explore the relation between complexity of structure and behaviour, two sorts of models have been made. One is the Homeostat described by W. R. Ashby in *Electronic Engineering* (December 1948) which maintains its internal dynamic stability by selecting its own internal circuit whatever external stresses are applied. An interesting philosophical point illustrated by this machine is that although the designer has a complete wiring diagram, neither he nor any other observer can tell from observation of the machine's behaviour what the precise circuit is at any given moment. This model of homeostasis does nothing except maintain its *internal* stability; it is rather like a sleeping animal which will stir if made uncomfortable and settle down to sleep in a new position.

In another class of electro-mechanical evolution are the model organisms on which I have been working. Popularly referred to as 'tortoises', these are mobile electro-mechanical robots and are seen in the photograph reproduced overleaf. Their descriptive title is *Machina speculatrix*.

These have been designed to demonstrate the following principles which seem to appear in most living creatures.

1. *Parsimony*, that is, economy of structure and function. There are very few redundant organs in present-day animals and many parts of the body were originally something quite different. 'Mend-and-make-do' is a popular slogan in the struggle for existence. In *Machina speculatrix* the number of units corresponding to nerve cells has been limited to two; there are two valves of miniature type, two relays, two condensers, two miniature electric motors, two batteries, and two 'receptors', one a photo-electric cell which gives the organism sensitivity to light and a sensitive electrical contact serving as a touch receptor which gives it responsiveness to material obstacles. In spite of this extreme economy of structure the machines exhibit a wide variety of behaviour patterns which, though strictly determined in the sense that no random element has been introduced, are unpredictable even by their designer.

2. *Speculation*, that is the propensity to explore the environment actively rather than to wait passively for something to happen. It is this faculty which gives the device its specific name and distinguishes it from most other machines; the most elaborate computing engine does not look round for problems to solve and even the Homeostat does not actively look for trouble, though it can readjust itself when disturbed by the experimenter. *Machina speculatrix* is never still except when 'feeding' (that is, when the batteries are being recharged), but, like the restless creatures in a drop of pond water, bustles around in a series of swooping curves so that in an hour it will investigate several hundred square feet of ground. In its exploration of an ordinary room it inevitably encounters many obstacles, but, apart from stairs and fur rugs, there are few situations from which it cannot extricate itself. What it searches for and how it avoids obstacles is explained in the next section.

3. *Positive tropism*, that is attraction to certain perceptible variables. The one positive tropism of *Machina speculatrix* is exhibited by its movement towards lights of moderate intensity. The photo-cell, amplifier and motors are connected in such a way that when an adequate light signal is received the exploratory behaviour is checked and the organism orientates itself towards the light and approaches it. Until it 'sees' a light the photo-precetor is in continuous rotation, scanning the horizon for light signals, and this scanning process is linked with the steering mechanism in such a way that the 'eye' is always looking in the direction of movement; thus, when a signal is received from any direction the machine is in a position to respond without too much manœuvring.

4. *Negative tropism*. Certain perceptible variables such

The author with two of his electro-mechanical 'tortoises'. On top of each is a photo-electric cell which is rotated by a motor and continues to revolve steadily so long as it does not receive the 'stimulus' of light from a sufficiently strong source; at the same time the front wheel of the tricycle undercarriage, which is coupled to the same motor, is spinning about a vertical axis as well as turning on its axle while the two back wheels are static so that the effect is that the animal swivels around in a series of jerks. As soon as a strong enough light impinges on the photo-electric cell, the 'tortoise' stops revolving, the motor operating the front wheel is cut out and the back wheels start moving, to propel the 'tortoise' towards the light. The 'tortoise' can also negotiate obstacles; when it hits an object, the pressure on the shell or camera causes a short circuit of the photo-electric cell mechanism and the 'tortoise' proceeds to move more or less at random until it is free of the obstacle, when the original circuit is again completed and the 'tortoise' can proceed to move off under the control of the photo-electric cell. Dr. Walter is planning to build similar robots with an electronic system which will endow them with a 'memory.'

as bright lights, material obstacles and steep gradients are repellent to *M. speculatrix*; in other words, it shows negative tropism towards these stimuli. Observing the principle of parsimony, this is accomplished without introduction of additional components by making any slight displacement of the organism's shell close a contact which converts the photo amplifier into an oscillator; this causes alternating movements of butting and withdrawal, so that the robot pushes light obstacles out of the way, and goes round heavy ones. This device automatically introduces the next important principle.

5. *Discernment*, that is, distinction between effective and ineffective behaviour. When the machine is moving towards an attractive light and meets an obstacle, the induction of internal oscillation does not merely provide a means of escape—it also eliminates the attractiveness of the light, which has no interest for the machine until after the obstacle has been dealt with. There is a brief memory of the obstacle, so that the search for lights and attraction to them when found is not resumed for a second or so after a material conflict.

6. *Optima*, that is, a tendency to seek conditions with moderate and most favourable properties rather than maxima. The circuit of *M. speculatrix* is so adjusted that, while exploration is undertaken in darkness and moderate lights are attractive, bright lights are repulsive. Thus the machine can avoid the fate of the moth in the candle and also, with the scanning device, the dilemma of Buridan's Ass which starved to death because two exactly equal piles of hay were precisely the same distance away, since, if placed equidistant from two equal lights, *M. speculatrix* will not aim itself half-way between them, but will visit first one and then the other.

7. *Self-recognition.* The machines are fitted with a small flash-lamp bulb in the head which is turned off automatically whenever the photo-cell receives an adequate light signal. When a mirror or white surface is encountered, the reflected light from the head-lamp is sufficient to operate

the circuit controlling the robot's response to light so that the machine makes for its own reflection, but as it does so the light is extinguished which means that the stimulus is cut off—but removal of the stimulus restores the light, which is again seen as a stimulus, and so on. The creature therefore lingers before a mirror, flickering and jigging like a clumsy Narcissus. The behaviour of a creature thus engaged with its own reflection is quite specific, and on a purely empirical basis, if it were observed in an animal, might be accepted as evidence of some degree of self-awareness. In this way the machine is superior to many quite 'high' animals who usually treat their reflecion as if it were another animal if they accept it at all. This leads on to:

8. *Mutual recognition.* Two creatures of the same type, attracted by one another's light, both extinguish the source of attraction in themselves in the act of seeking it in others. Therefore when no other attraction is presented a number of the machines cannot escape from one another, but nor can they ever consummate their 'desire', and when seen from the back or side a fellow creature is merely an obstacle. In a sense, then, a population of machines forms a sort of community with a special code of behaviour. When an external stimulus is applied to all members of such a community, they will of course see it independently; but the more individuals there are the smaller the chance of any one achieving its goal, for each individual finds in the others converging obstacles.

9. *Internal stability.* One of the advantages of making a moderate light a positive stimulus is that this can be used as a sign or symbol for the energy which the creatures require for their sustenance—electricity. A light is placed in their 'hutch' in such a position that they are attracted to it, and therefore tend to enter the hutch of their own accord. However, when their batteries are fully charged the intensity of the light operates the repelling circuit when they are just over the threshold and they withdraw for further exploration. When their batteries require recharging on the other hand their sensitivity is reduced and the light continues to exert an attraction until they are well within their quarters. At this point contacts on the side of the shell can engage with others in the hutch, thus closing the battery-charging circuit. Current flowing in this circuit operates a relay which turns off the power to their nervous and motor systems so that the machine remains motionless until, the battery voltage having risen, the charging current falls and their internal mechanism is once again energised. This arrangement is very far from perfect; there is no doubt that if left to themselves a majority of the creatures would perish by the wayside, their supplies of energy exhausted in the search for significant illumination or in conflict with immovable obstacles or insatiable fellow creatures.

This is all that the present models will do, but observation of their behaviour within these limits suggests that an anatomical circuit containing only two elements is enough to provide behaviour patterns of unpredictable complexity. More elaborate models in construction have devices to mimic the processes of learning, mutual aid and advanced social behaviour. The generation and treatment of their 'neuroses' and other breakdowns are likely to prove of particular interest, since even in the present simple models what psychologists call 'conflict situations' set up disturbances which can be put right only by the methods used in the clinic—rest, reassurance, or shock.

The interest of these experiments is manifold. Firstly, there is the relatively trivial aspect of the creatures as toys. They are certainly as entertaining as most mechanical playthings, either when left to roam at will or as a floor game. Two players with flashlamps can spend a busy hour trying to entice one another's tortoise into their own base, each using his own beast both aggressively and defensively. Secondly, models of this sort can be used to demonstrate many of the physiological mechanisms known to operate in the nervous system. Everyone is conscious of the fact that small sudden changes are more readily appreciated than slow ones (getting into a hot bath, for example) and similarly that one gets used to many things after a certain time. Such a response to the rate of change rather than to the absolute level or steady state is represented mathematically by differentiation. It was found essential to incorporate in *M. speculatrix* a simple circuit which performs this operation on weak stimuli in order to obtain adequate sensitivity over a wide range of intensities. But we also know that very strong stimuli (pain) do not become less intense with time. In *M. speculatrix* too, the response to powerful stimuli is not differentiated so that a bright light or an obstacle exerts a steady repulsion. The exploratory and orientating behaviour again is obtained by a process of 'scanning' which may be analogous to that found in the brain; the photo-cell is swept steadily round and round until a light is found and at that instant the rotation is checked. Moreover the steering machinery is locked to the visual scanning system so that wherever a light is seen, thither the creature will tend to move. A similar relation between sensory and motor systems is believed to exist in the brain.

It should be confessed that several of these analogies were unintentional and were not appreciated until the first machines had been made; they emerged as practical features of design, necessary to satisfy at the same time the performance and economy specifications. Perhaps even more satisfying is the unexpected appearance of functions which are found in living animals, simply as the result of the combination and permutation of simple mechanisms, for this makes possible the elaboration of rigorous hypotheses to account for some of the features of animal behaviour previously regarded as beyond the scope of scientific law. What is more, these hypotheses can be tested by experiment. With such tactics it may be possible to infiltrate into the territory claimed by philosophers as inaccessible to quantitative science. No serious person would deny out of hand the possibility of transcendental properties in living creatures, but if such concepts as free-will and consciousness are to be retained, it is essential for clear thought that they should be deployed only after the breakdown of scientific explanation leaves a definite gap in reasoning, not as a deterrent to serious study or sincere speculation.

In comparing these machines with the creatures of mythology and the clockwork automata, the most important difference is that their mimicry of living beings is confined to the system of control and behaviour—no special effort has been made to give them a life-like appearance, though this could easily be done. The present models are to natural animals as Caliban to Ariel.

In conclusion these devices share one function with religious statuary and painting—far from degrading the mystery which they represent, they focus and magnify one's humble respect for the world of authentic life.

Parasitic 'Water-fleas'

THE popular name of water-flea which is applied to many small crustacea refers to the creatures' small size and leaping movements rather than to any parasitic habit. The two best-known water-fleas, *Daphnia* and *Cyclops*, common in any standing water, belong to two different orders of Crustacea, the Cladocera and Copepoda respectively. The first of these contains practically no parasitic members; but the Copepoda have exploited this way of life very often in the course of evolution. A measure of the advantages of this way of life is given by the fact that parasitic copepods are, in general, considerably larger than their free-living relatives.

All manner of aquatic animals, especially marine ones from worms, molluscs, and crustacea to fishes and whales, are liable to carry these parasites. Many of the great basking sharks recently harpooned off the west coast of Scotland have been found to have the parasitic copepod *Dinematura producta* (Fig. 1) attached to their fins and on other parts of the body. The anatomical structure of *Dinematura* is basically the same as that of the free-living copepod *Cyclops* (Fig. 1), so well known to microscopists and students of fresh-water biology; but in detail it shows many adaptations to a parasitic existence. There is a similar median eye; both pairs of antennae are comparatively short and are armed with strong hooks for clinging to the skin of the host. The mandibles and other limbs associated with the mouth, which in *Cyclops* are adapted for use in capturing and manipulating solid food, are modified into piercing and sucking instruments. The four pairs of swimming limbs behind these are, however, very similar in the two genera and the abdomen ends in a caudal fork armed with setae in both. *Dinematura*, is about 2 centimetres long while *Cyclops* is only as many millimetres. It follows that while its mass is about a thousand times as great, if its shape were the same the superficial area would only be increased about a hundred times. As copepods respire through the general body surface this would hardly be sufficient even taking into account the sedentary existence of the parasite compared with the active life of *Cyclops*. This may be why the body of *Dinematura*, instead of being simply pear-shaped, has a number of lobes projecting from the thoracic segments which increase the surface area. The head of *Dinematura* is in the form of a shallow dome with the free edge capable of fitting closely against the skin of the shark in much the same way as the shell of a limpet fits against a rock. This form is that least likely to be dislodged by wave shock or by the movements of the shark in the water. A conspicuous feature of *Dinematura*, and of most parasitic copepods, is the presence in the female of a pair of egg strings; in *Dinematura* these may be as much as four times as long as the animal itself.

While there is no difficulty in recognising that a parasite like *Dinematura* is closely related zoologically to *Cyclops*, this is by no means the case with many other parasitic copepods whose structure has become so degenerate in the adult that until the life histories were discovered they were not recognised as being crustacea, let alone copepods. *Lernaeocera* (Fig. 3), the 'gill-maggot', whose blood-red, bloated, S-shaped body is often to be seen on the gills of cod sold in fishmonger's shops, looks much more like a worm than like a crustacean. It was placed in the miscellaneous collection of worm-like creatures, called *Vermes*, by Linnaeus and others following him until its life history was worked out. Like other copepods *Lernaeocera* hatches from the egg as a nauplius larva Fig. 2 (*2*), which has a simple oval body, a single median eye, and only three pairs of limbs.

This nauplius grows and moults a few times until it reaches the stage when it bears some resemblance to the adult *Cyclops*. It then becomes parasitic on the gills of a fish of the plaice family and retrogressive changes take place. The power of movement is lost and the limbs become reduced to simple stumps. Later the parasite regains the power of movement and leaves its first host in the form of a typical free-living copepod. Sexual maturity has now been attained and pairing takes place. The male develops no farther, but the female searches for a second host, this time a fish of the cod family. Again the gills of the fish are attacked; the female proceeds to burrow until the whole of the front part of the body is embedded in the tissues.

The genital segment becomes much distended to form the greater part of the worm-like body to which the coiled egg strings are attached. Degeneration is even more extreme in another family (the Heryllobiidae), the members of which are parasitic in marine invertebrates. The adult female is entirely without limbs (these are present in *Lernaeocera* though they are microscopic and functionless), and is attached by a tubular process which ramifies within the body of the host. A number of small males, which are also limbless, are attached to the female near the genital apertures.

The life history of members of the family known as the Monstrilloida is perhaps the most extraordinary of all (Fig. 3). The young hatches as a nauplius without a mouth or even a gut. The nauplius burrows into the body of its host, a polychaete worm, casting its skin in the process and losing its limbs, so that by the time it reaches the body cavity of the host, where it lodges, it consists of no more than a naked mass of embryonic cells. A thin cuticle is now secreted and a pair of horn-like processes grow out from one end of the oval mass, presumably for the absorption of nourishment. The organs of the adult gradually develop inside and the sac-like case becomes pointed at the end farthest from the horns, and around this point, and directed away from it, arise several rows of spines. These apparently enable the parasite to bore its way out from the body of its host. A single moult takes place and the adult emerges as a free-swimming copepod very like *Cyclops* in appearance. It is complete as far as first antennae, swimming legs, abdomen, and caudal fork are concerned; but there is no trace of second antennae, mandibles, or other mouth parts and only the vestige of an alimentary canal. The animal passes its whole life without a gut, and cannot feed either when it first hatches as a nauplius or when it finally moults to its adult form, the two stages of its life history which bear some resemblance to those of a normal copepod. In between these two free-swimming stages, one at each end of its life, it exists as a bag of cells absorbing nourishment from the tissues of its host through a pair of horns.

J. P. HARDING, Ph.D., F.Z.S.

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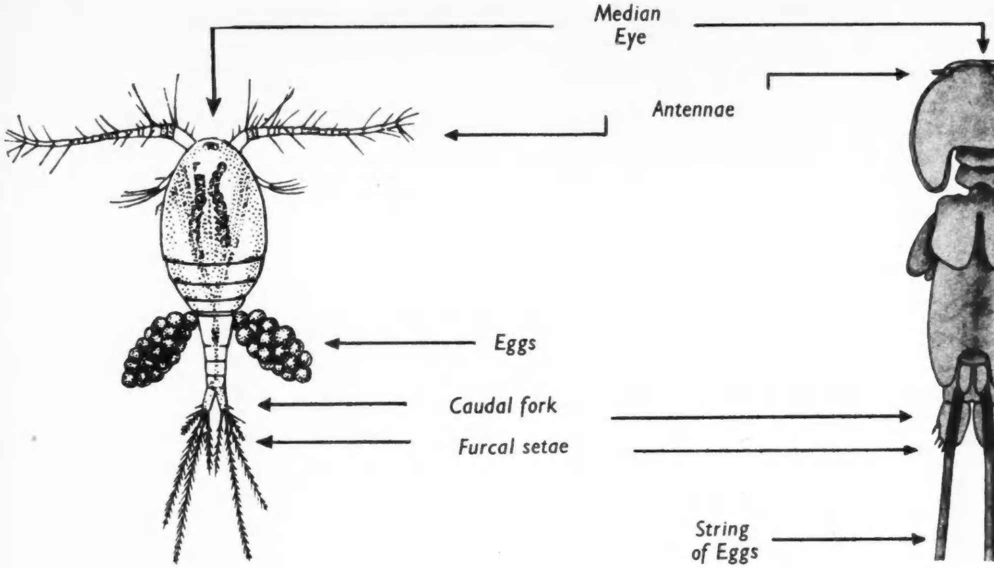
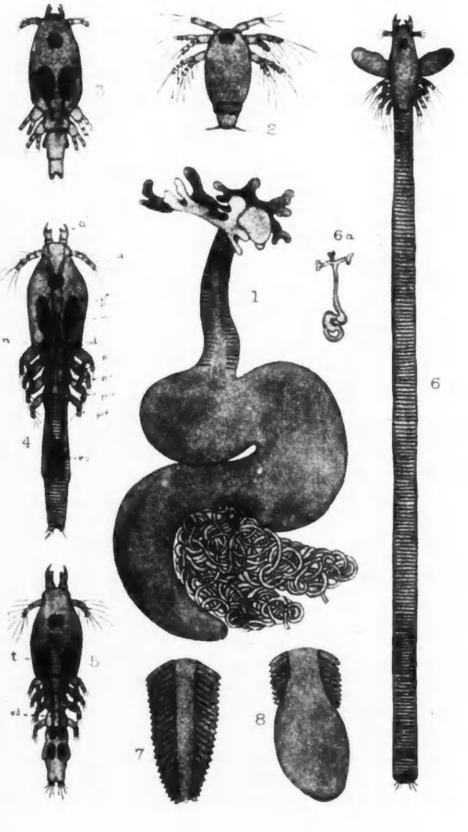


FIG. 1 (*Left*).—*Cyclops* which swim in ponds and ditches everywhere, and will serve to show the basic pattern of the copepods. (Magnified 30 times.) (*Right*) The shark-parasite *Dinematura* for comparison with *Cyclops*. The most conspicuous difference is the presence of projecting lobes on the thorax, and the larger size. (Magnified 3 times.)



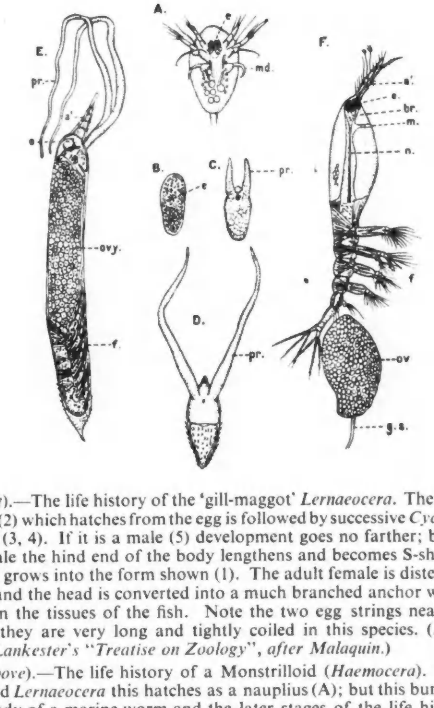


FIG. 2 (*Left*).—The life history of the 'gill-maggot' *Lernaeocera*. The nauplius larva (2) which hatches from the egg is followed by successive *Cyclops*-like stages (3, 4). If it is a male (5) development goes no farther; but if it is a female the hind end of the body lengthens and becomes S-shaped (6, 6*a*) and grows into the form shown (1). The adult female is distended with eggs and the head is converted into a much branched anchor which is buried in the tissues of the fish. Note the two egg strings near the hind end, they are very long and tightly coiled in this species. (*From Lankester's "Treatise on Zoology", after Malaquin.*)

FIG. 3 (*Above*).—The life history of a Monstrilloid (*Haemocera*). Like *Cyclops* and *Lernaeocera* this hatches as a nauplius (A); but this burrows into the body of a marine worm and the later stages of the life history (B, C, D, E) are very different. The final stage (F), like the first, is free-swimming; the female is shown, it bears some resemblance to *Cyclops*. *a*, first antenna; *e*, eye; *f*, swimming feet; *ov*, egg sac; *ovy*, ovary; *pr*, absorptive processes.

(*From "British Parasitic Copepoda" by T. and A. Scott.*)

FIG. 1.—The largest wind-generator constructed so far was an experimental unit built on a hill in Vermont by the S. Morgan Smith Company. Its propeller swept a circle 175 ft. in diameter.

FIG. 2.—Artist's impression of the 100-kilowatt generator to be erected on Costa Head, Orkney. The area swept by the propeller blades is 60 ft. in diameter.

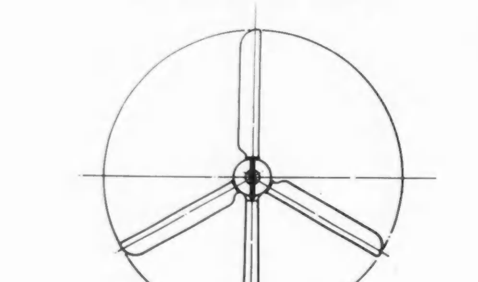


FIG. 3.—Front elevation of an experimental 100-kilowatt wind-driven generator which is being developed in Britain. (*Courtesy, Enfield Cables Ltd.*)

FIG. 4.—The regions of high winds in Britain. The average annual wind speed for the heavily shaded zone is 16–18 m.p.h.; for the more lightly shaded zone, 14–16 m.p.h.

Electricity from the Wind

E. W. GOLDING, M.Sc.Tech., M.I.E.E.

In the days before the war abundant supplies of cheap coal and oil gave little incentive to serious consideration of wind power for large-scale production of electric power. A few small wind-driven generators were used to provide electric light for isolated premises in windy districts, but these were looked upon rather as interesting toys. This situation has now changed. There is no longer abundance of cheap fuel. Coal is badly needed for export and for important, recently developed, industrial processes. The costs of generating electricity have risen considerably with small prospect of their falling much in the future; yet the demand for electricity is ever increasing.

Under these circumstances the fact that our western coastal districts are among the windiest in the world becomes significant. Considering only the first few hundred feet above the ground, literally millions of horsepower cross our coasts on a windy day.

The Economy of the Method

Wind power is, of course, free and inexhaustible while coal deposits are rapidly becoming exhausted. The wind has, however, two main disadvantages which must be countered if it is to be used economically for electricity supply. These are: (i) the low energy content per unit volume of a fluid so tenuous as air, and (ii) uncertain availability at any particular time. The first implies a relatively large, and rather expensive, structure to tap an appreciable amount of power while the second suggests storage—which is also expensive—to carry over energy from windy days for use during calm spells. Thus, although the source of the energy itself is free, costs are involved in abstracting and converting it for use. The annual costs of operating a wind power plant are those for interest and depreciation on the initial outlay, plus a small amount for maintenance, and these costs must clearly be compared with the annual value of the energy obtained from the plant.

For this form of generation to be economic therefore, the costs of constructing the plant must be kept as low as possible and the sites chosen to give a large annual output of energy. Methods of storing energy which may be worth while adopting for small generating sets are ruled out in large-scale operation; wind power must be used as and when it is available. The best way to do this would be to erect the windmills on especially windy sites fairly close to electricity supply networks into which the output could be fed—fortunately the networks are now so widespread that connexion to them should not be difficult. Energy generated by the wind would replace that generated by coal in the thermal power stations so that, in this way, wind power would act as a fuel saver.

As for the windmill generators themselves, there should be good hope of their construction being undertaken reasonably cheaply in view of the great experience gained in building aircraft during recent years.

The cost per unit of electrical energy (i.e. kilowatt-hour) generated by large wind-driven generators can be estimated as follows. The cost per kilowatt of plant capacity may be between £50 and £80. Taking a life of 20 years, an interest rate of 3% as applying to capital borrowed by supply authorities under Government control, and allowing 1–2% for maintenance, the annual capital charges would be about 8% or £4–£6 8s. per kilowatt. At a good site the plant would give an output equivalent to its running at full capacity for 4000 hours per annum. Thus 4000 kilowatt-hours per annum may cost between £4 and £6 8s., which corresponds to 0·24d. to 0·38d. per unit. Such a cost compares favourably with the fuel component of generating cost in a steam-driven power station for which an average figure is about 0·4d. This is a fair comparison since wind power would be mainly a coal saver; it cannot replace other generating plant, which must be available to carry the whole of the load when there is no wind. Incidentally this estimated cost is only of the order of one-twentieth of that applying to small wind-driven generators which are relatively much more costly to construct and maintain and which cannot be sited nearly so favourably.

On islands and in other remote districts small diesel-driven power stations are common; a typical generating cost is then 0·65d. for the fuel component so that a windmill should be especially advantageous at such places which are—rather fortunately—often quite windy.

This brief outline of the economic position in wind power generation is sufficient to show the advantage which may be gained and the new aspect which is opened up by its utilisation on a large scale.

Wind Power Sites

Early in 1948 the British Electrical and Allied Industries Research Association established a Committee to be responsible for research on wind power generation. After some preliminary studies which showed that there were prospects of the method proving economical the first research programme was started. This was a survey to find the best sites in Great Britain for windmill generators and to furnish data for an estimate of the total annual energy which it might be practicable to obtain.

The districts which long-term meteorological records showed to have the highest annual average wind speeds (Fig. 4) were first chosen for fuller investigation. Now, to obtain a satisfactory annual output from a windmill generator of economic design an annual average wind speed of at least 20 miles per hour is desirable. The map shows that this figure is higher than that applying in general to any district in Great Britain. But there are sites in every district which have wind speeds higher than the average. Three factors bring this about: exposure, i.e. freedom from screening by higher surrounding country, altitude and topography. The choice of a hill-top is obvious because wind speed increases with height. Further, a fairly steep, smooth hill acts like an aerofoil and speeds up the wind over its summit through the compression of the air stream as it ascends the hill-side (Fig. 5). A ridge

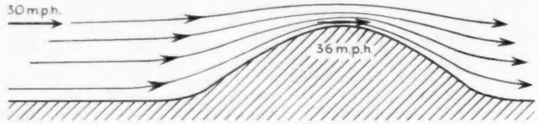


FIG. 5.—Wind passing over a steep, smooth hill is speeded up. Thus a wind which reached the hill with a speed of 30 m.p.h. may be moving at 36 m.p.h. over the hill-top.

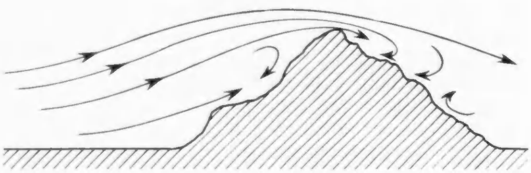


FIG. 6.—This diagram shows the turbulent air flow that is associated with an irregularly shaped hill.

lying athwart the prevailing wind may give even better results than a round hill. Precipitous faces must be avoided as they produce turbulence which could wreck the windmill (Fig. 6).

At the outset, proximity of an electricity supply line to absorb the energy generated is very desirable, because transmission over a long distance is expensive, but this may not be so important later, particularly if sites can be found on which a large generating capacity can be installed—producing sufficient power to be worth fetching from a distance.

The search for good sites has already been well rewarded; hill-tops have been found in Orkney, North and South Wales and Cornwall which, during measuring periods extending to twelve months in some cases, have had average wind speeds at least fifty per cent higher than those for the surrounding district.

Although meteorologists have collected a considerable body of data on winds in general, not much seems to be known about the behaviour of wind flowing over hills. Research was called for on a number of questions—such questions as: What shape of hill gives the greatest speed-up of the wind? At what height above the summit does maximum wind speed occur? What variations of wind speed are likely to exist over the area swept by the blades of a windmill generator? What maximum wind speeds and rates of change both of magnitude and direction are likely to be encountered in gusts? Answers to these questions and others which have an important bearing upon the siting and design of such generators should be forthcoming from theoretical studies, laboratory tests on models and measurements, on hills of different shapes, which are now under way.

To judge the wind-power potentialities of any particular site it is first necessary to obtain its 'wind régime'. Measurements of the average wind speeds, hour by hour, are made and these are analysed and converted into a 'velocity duration' curve for the site. This shows the various wind speeds plotted on a base of hours in the year for which these speeds are equalled or exceeded.

A windmill extracts energy from the wind passing through the area which is swept out by the propeller or rotor during its rotation and, for a given swept area, the power available is proportional to the *cube* of the wind speed.

One is justified in saying that successful exploitation of wind power can be resolved into a matter of choosing a good site and then designing and building a robust and easily maintained windmill generator to match the wind régime and to take full advantage of it without undue cost of construction.

From the progress already made in the survey being carried out it appears that there may be several hundred sites in Great Britain on each of which economic windmills with a capacity of 2000 kilowatts or more may be built. If development to this degree does indeed prove justifiable—not overlooking the fact that many snags have yet to be met and overcome—a total capacity of between one and two million kilowatts may thus be installed, giving an annual energy output of between 4000 and 8000 million kilowatt hours and saving between two and four million tons of coal a year.

Much research remains to be done before a prototype of the most economic form of wind driven generator can be built. Dozens, perhaps even hundreds, of designs of all shapes and sizes up to 60,000 kilowatts have been suggested in this and other countries during the past few decades. The largest ever known to be built and operated—the 1250 kilowatt plant shown in Fig. 1—was of the propeller type, as are the largest (50 to 70 kW) sets used in Denmark. It may possibly be proved, however, that some different type will be superior to this.

To gain some experience in actual operation of a windmill generator connected to a supply network the North of Scotland Hydro-Electric Board, who are responsible for electricity supply in the sparsely populated districts of Northern Scotland, are installing a 100 kW pilot plant (Fig. 2) on Costa Head, Orkney, and this will feed energy into an adjacent network. This set, which will have a propeller 60 feet in diameter and a steel tower of about 80 feet in height, is being built by John Brown & Co. Ltd., and it should undoubtedly provide very valuable information on both the problems to be met and the output which may be obtained from this site which wind measurements over more than 12 months have shown to have an annual average wind speed of around 25 m.p.h.

The unconventional Andreau design shown in outline in in Fig. 3 is interesting. It comprises a hollow propeller with three blades which are open at the tips; a hollow hub and tubular air duct and, at the bottom, an air turbine driving the generator itself. When the propeller rotates the air is expelled from the tips by centrifugal force—this creates a vacuum so that air is sucked through the air turbine and up the vertical air duct. One of the obvious advantages of such a unit is that the weighty machines are kept down at ground level.

READING LIST

"*Power from the Wind*", by P. C. Putman (D. Van Nostrand Co. Inc.).

"The potentialities of wind power for electricity generation (with special reference to small-scale operation)", by E. W. Golding and A. H. Stodhart, *E.R.A. Technical Report*, W/T16.

"Large-scale generation of electricity by wind power—preliminary report", by E. W. Golding, *E.R.A. Technical Report*, C/T101.

Far and Near

More Science at 1951 Exhibition

Two exhibitions of scientific interest supplementary to the main Festival of Britain exhibition on the South Bank of the Thames will be held during 1951. There will be an Exhibition of Science on the ground floor and basement of what will, after the Festival, be the new wing of the Science Museum in South Kensington.

An Exhibition of Industrial Power will be held in Glasgow in the Kelvin Hall. The purpose of this exhibition is to show the achievements of British heavy engineering and its associated technologies and will be based on the present source of our industrial power, coal and water, and the potential source of the future—nuclear energy. The display on the use of coal will cover mining, the manufacture of iron and steel, the generation and transmission of electricity and the story of railways and shipbuilding. Hydro-electric schemes, civil engineering and irrigation will illustrate the use of water power. The organiser of this exhibition is Alastair Borthwick, and the chief architect and designer is Basil Spence.

Describing the Exhibition of Science to a press conference, Sir Edward Appleton, F.R.S., said, "A limited topic has been chosen for exposition—the growth of our understanding of the nature and architecture of matter. This subject can certainly be regarded as coming within the domain of pure science though in the Exhibition appropriate references are made to the surprising way in which technological advances have followed this development of man's more detailed insight into atomic and nuclear structures. Perhaps this Exhibition will appeal most to those members of the public who, without being expert, have a general leaning towards scientific matters.

"The method of treatment, as always, proceeds from the familiar to the unfamiliar; and the visitor will be led, by easy steps, from his normal acquaintance with matter in its solid, liquid and gaseous form, first to an understanding of the atomic and molecular 'bricks' of which such materials are composed and then, beyond the atom, to the fundamental particles of which the atom is itself composed. Finally, and here excitement must surely reach its zenith, we are to be shown the inner structure of the nucleus, that citadel of the atom, from which energy can now be unleashed for man's glory or ruin." This exhibition is being designed by Brian Peake.

Owing to the limited space available for the display of the achievements of science a very careful selection of topics for exhibition has had to be made. To advise on the general policy behind the scientific exhibitions a special Council for Science and Technology was formed and specialist panels for each main science are undertaking further selection in their own particular fields. The chairman of the Council is Sir Alan Barlow and its members are Sir Wallace Akers, Colonel Sir Stanley Angwin, Sir Alfred Egerton, F.R.S., Sir William Halcrow, Sir Ben Lockspeiser, F.R.S., Sir Edward Salisbury, F.R.S., Sir Frank Smith, F.R.S., Professor Andrew Robertson, F.R.S., Dr. H. P. Himsworth and Mr. E. H. E. Havelock. The Executive officer of the Council is Mr. Ian Cox, who is also Director of Science for the Festival. Mr. Cox is well known for his work as a scientific publicist; he used to be with the B.B.C. for whom he produced the original series of "Science Survey" talks in conjunction with Prof. E. N. da C. Andrade.

A Great Woman Astronomer

WOMEN of science, in contrast to 'men of science', are rare enough to attract particular attention in commemorating the eminent of the past. Caroline Lucretia Herschel, born on March 16, 1750, though at first seemingly doomed to household drudgery and then turning to the concert platform as a singer, upheld the renown of the Herschel family of astronomers by discovering nebulae and a number of comets, and then taking the Astronomical Society's Gold Medal in her stride. She rendered invaluable aid to her celebrated brother, William Herschel, taking down his observations and calculations, preparing his star catalogues for publication in the *Philosophical Transactions*, and grinding and polishing mirrors for him.

But her own original work won the attention it deserved. Her "Index to Flamsteed's Observations of the Fixed Stars" and her published *Errata*, both presented before the Royal Society, are examples of this.

A.Sc.W. and Social Scientists

THE Association of Scientific Workers has formed a new branch for Social Scientists. For the first time, all social scientists are offered an organisation and meeting place for the consideration of the role of the social sciences in society, professional problems concerning salaries and the proper employment of social scientists. The branch, though primarily covering the London area is open to social scientists all over the country. Interested readers should write to the branch secretary, Peter Brinson, c/o Association of Scientific Workers, 15, Half Moon Street, London, W.1.

World Power Conference

A COPY of the programme for the Fourth World Power Conference to be held in London on July 10 to 15 can now be obtained from: The Conference Offices, Fourth World Power Conference, 414 Cecil Chambers, 76–86 Strand, London, W.C.2.

A Rare Deep-sea Fish: Readers' Help Wanted

APPEALS to DISCOVERY readers to assist research workers requiring the services of widely scattered observers have in the past met with a ready response and have produced some very useful results. Our readers are now invited by Mr. D. W. Tucker of the British Museum (Natural History) to collaborate in an investigation of the distribution of a species of deep-sea fish.

Mr. Tucker writes as follows:

"The Black Scabbard Fish, *Aphanopus carbo*, lives at depths down to 800 fathoms in the Eastern and North-Eastern Atlantic, and is occasionally taken by fishing boats in deep water off the west of Scotland and Ireland. (*Ref.* Tucker and Palmer, *Nature*, 1949, Vol. 164, pp. 930–31). It is easily recognised from the accompanying illustration, and grows to over a yard in length. The body has no scales, and is covered with a thin, black, glossy skin which easily peels off, leaving white patches. The mouth has formidable teeth, there are two long dorsal fins, and a short stout spine behind the vent which may be poisonous and should be treated with respect.

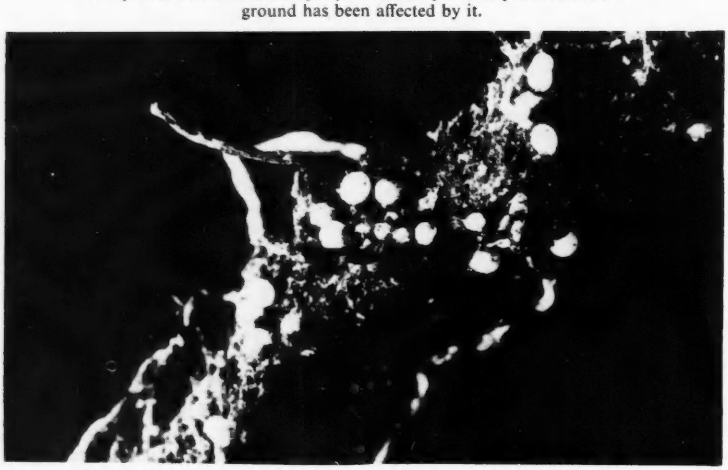
"I am investigating the general biology of this species, its distribution, migrations, food and life-cycle, and should be most grateful for specimens and records. Actual specimens (not gutted), will be preferable, with details of the date of capture, the latitude, longitude and depth, the number of individuals taken, the type of gear used, and the other fishes caught at the same time. While such information and material is best collected by fishermen and those living in the western ports, I should also be glad to hear of any specimens seen in fish markets, with such data as to port of origin, etc. that readers can obtain."

Specimens and information should be addressed to:

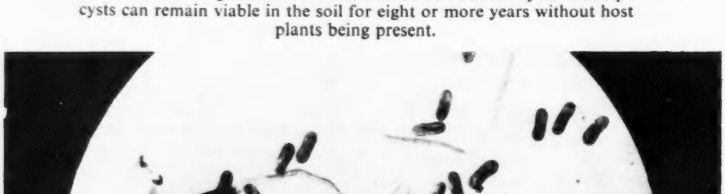
Mr. D. W. Tucker, Department of Zoology, British Museum (Natural History), Cromwell Road, London, S.W.7.

Natural History Museum copyright

The potato eelworm is a major pest in Europe. The patch in the foreground has been affected by it.



Potato root enlarged to show white immature eelworm cysts. The ripe cysts can remain viable in the soil for eight or more years without host plants being present.



A mature cyst that has ruptured, showing eggs and young eelworms. A method of control might be perfected if chemists can find a cheap hatching factor.

(*Photos by Prof. H. W. Miles, Wye College.*)

The Potato Eelworm Hatching Factor

THE potato eelworm has been described as the greatest menace to future crop production as infestation is already costing about two million pounds a year and is still spreading. The small nematode, *Heterodera rostochiensis*, is parasitic upon potato roots into which the larvae bore. When maturity is attained, the males leave the roots for the soil, but the females remain attached to the roots by their heads. After fertilisation, the body of the female swells up with eggs and eventually forms a brown cyst containing several hundred fully-formed larvae. The cysts drop off into the soil and there lie dormant until stimulated to hatch, and can remain at least partially viable for up to ten years. When the next crop of potatoes is grown, the cysts are stimulated to hatch by some agent secreted into the soil by the potato roots. The nature of this specific eelworm hatching factor is of great biological interest. If it, or an effective substitute, could be manufactured cheaply, a new method of eelworm control might be possible. The cysts might be hoaxed into hatching in the absence of a suitable host plant, and after the larvae had died of starvation, potatoes could be planted in the clean ground. A group of workers has been studying this hatching factor, trying to isolate and identify it and seeking active synthetic compounds. An account of their results obtained during the past decade has just been published. Active material can be obtained from the leachings of soil in which potatoes, tomatoes or plants of black nightshade (*Solanum nigrun*) are growing. Tomato plants were chosen as a source of material as these are readily grown and handled in bulk indoors. Large numbers of plants were grown in soil, watered frequently and the leachings collected and treated with a special charcoal which absorbed the active material. The active material was extracted from the charcoal with acetone, and after removal of this solvent a brownish solid was obtained which showed high activity. The amount was small—only about an ounce of solid being obtained during a year from the continuous cultivation of 4000 to 5000 plants, and even this solid probably contained less than 2% of the pure hatching factor. Crude material has been further purified to yield a yellow gum which showed full hatching activity at a dilution of one part in a hundred million of water. This gum has not been crystallised so its purity is still in doubt, but useful evidence about its chemical nature has been obtained, suggesting that the factor, now called *eclepic acid*, is an unsaturated hydroxy lactonic acid. A number of model compounds have been made displaying some of these structural features and a few have shown distinct activity but at best only about one ten thousandth of that of the natural eclepic acid. The determination of the structure of eclepic acid and its subsequent synthesis remain as challenges to the organic chemist, who is handicapped by the difficulty of obtaining enough of the natural factor for adequate examination. Readers will find papers on the Potato Eelworm hatching factor in *Biochemical Journal*, 1949, **45**, 513–537, by C. T. Calam, D. H. Marrian, H. Raistrick, P. B. Russell, A. R. Todd and W. S. Waring.

Prizes for Science Essays

ENDEAVOUR, the I.C.I. science magazine, has offered the sum of 85 guineas to be awarded as prizes for essays submitted on a scientific subject. The primary purpose of these awards is to stimulate younger scientists to take an interest in the work of the British Association, and so to raise the literary standard of scientific writing. The competition is restricted to those who are not more than twenty-five years of age on June 25 this year. Three prizes will be awarded: a first prize of 50 guineas, a second prize of 25 guineas, and a third prize of 10 guineas. The subjects for the essays are as follows:

Modern Techniques in Astrophysics; Phenomena at Low Temperatures; The Literature of Science; Radioactive Tracers; Metallic Corrosion; Macromolecules; The History and Significance of Common Salt; The Scientific Method; The Mechanism of Heredity; The Biological Significance of Trace Elements; Industrial Applications of Biology; The Earth's Crust.

The essays, which must be in English and typewritten, should not exceed 4000 words in length, and only one entry is permitted from each competitor.

The essays will be judged by the editors of *Endeavour* in consultation with representatives of the British Association, and the prizes will be awarded during the meeting of the British Association in Birmingham in September 1950.

All entries should be addressed to The Assistant Secretary, British Association for the Advancement of Science, Burlington House, Piccadilly, London, W.1., from whom full details can be obtained. Envelopes should also be marked *Endeavour Prize Essay*. The latest date for receipt of entries is June 26, 1950.

Centenary of Meteorological Society

THE Royal Meteorological Society, which is celebrating its centenary on April 3, was founded in 1850 "for the promotion of the science of meteorology in every aspect." There has always been close co-operation between the Society and the Government Meteorological Service, which was founded only three years after the Society. The Society continues to maintain a meteorological station in Camden Square, London. This station was established by G. J. Symons, president of the Society in 1900. The president is now Sir R. Watson-Watt, F.R.S.

The centenary celebrations will include a series of scientific symposia at Oxford, a meteorological exhibition at the Science Museum and a dinner. The exhibition, which is a public one, opens on March 27 and will run for three months.

Irving Langmuir Retires

DR. IRVING LANGMUIR, whose researches in the laboratories of the General Electric Company of America won him a Nobel Prize for chemistry in 1932, has retired after 40 years with the company. To his investigations the term 'fundamental research' should be applied rather than the term 'applied research'. As he himself has said of his work, "Whatever has come in industrial applications has come incidentally from experiments followed for their interest alone." On electron emission and gaseous discharges he did pioneer work, while his experiments with oil films on water uncovered a new branch of chemistry—surface chemistry.

Dr. Langmuir was once described as a man "who continually embarks upon mental voyages in regions so nearly airless that only the mind can breathe in comfort". It was on such 'voyages' that he developed the gas-filled incandescent lamp, the high-vacuum power tube, atomic hydrogen welding, a highly efficient screening-smoke generator for the army, and methods for artificial production of snow and rain from clouds.

The gas-filled lamp, which since its original development has been further improved by Dr. Langmuir and others, increased many times the efficiency of electric lamps. In terms of modern illumination levels, development of the gas-filled lamp and its subsequent improvements save the American people nearly three million dollars every night.

The high-vacuum power tube, which permitted use of high-voltage in radio sending and receiving for the first time, gave modern broadcasting its 'heart' and is regarded as one of the most important factors in development of that field.

Atomic hydrogen welding made possible for the first time the easy welding of aluminium and chromium and other hitherto unweldable metals and permitted welding of extremely thin sheets of metal, for which other welding techniques are unsuitable.

Developed by Dr. Langmuir and his protégé, Dr. Vincent J. Schaefer, a new technique for producing huge quantities of extremely dense screening smoke proved highly effective in concealing tactical movements of troops and supplies in combat in World War II and thus greatly safeguarded the lives of soldiers.

Dr. Langmuir's most recent work, conducted with Dr. Schaefer and Dr. Bernard Vonnegut, was the discovery of methods by which snow and rain can be produced from certain types of clouds. The team developed methods of producing snow and rain from super-cooled or below-freezing liquid clouds by seeding them either with dry-ice or with the compound silver iodide. Under these methods, snow is produced which may fall as snow, may change to rain, or may evaporate, depending upon atmospheric conditions. Dr. Langmuir developed a third method for producing rain directly from certain cumulus clouds of any temperature, by which method ordinary water dispensed into such clouds causes a chain-reaction rainfall.

Insecticides *v.* Swollen Shoot Disease

AGREEMENT has been reached between the Director of the West African Cocoa Research Institute at Tafo in the Gold Coast and Pest Control Ltd., whereby the latter will furnish a team of three scientists to work under the general administrative direction of the Director of the Institute on an investigation at Tafo of the possible use of systemic insecticides to control the spread of swollen shoot disease of cocoa in West Africa. The object of these experiments is not to kill the virus of swollen shoot disease but to kill the mealybug which is the vector of the disease. Thus, the most that the discovery of an effective systemic insecticide could achieve would be to prevent or reduce the spread of infection from trees infected with swollen shoot to healthy trees.

It is expected that three or four years at least must elapse before any conclusion, positive or negative, can be reached.

Night Sky in March

The Moon.—Full moon occurs on March 4d 10h 34m, U.T., and new moon on March 18d 15h 20m. The following conjunctions with the moon take place:

March			
4d 16h	Saturn in conjunction with the moon	Saturn	0°.3 N.
6d 06h	Mars ,,	Mars	4° N.
14d 18h	Venus ,,	Venus	9° N.
15d 20h	Jupiter ,,	Jupiter	3° N.
31d 23h	Saturn ,,	Saturn	0.1° N.

In addition to these conjunctions with the moon, Mercury is in conjunction with Jupiter on March 1d 15h, Mercury being 1.2° S.

Mercury is too close to the sun for favourable observation during March and is in superior conjunction on March 28, that is, the earth, sun and Mercury are nearly in a line. Venus can be recognised as a morning star, stellar magnitude —4.3, rising about 1½ hours before the sun during the month. A small telescope will show the increase in the visible portion of the illuminated disk from 0.2 to 0.4; the planet attains its greatest brilliancy on March 6. Mars rises at 20h 10m and 17h 10m at the beginning and end of March and can be seen in the constellation of Virgo. The planet is in opposition on March 23, that is, the sun, earth and Mars are nearly in a line, so that the sun sets about the same time as Mars rises. Jupiter is a morning star but is too close to the sun for favourable observation until the end of the month when it rises more than 1½ hours before the sun and can be seen for a short period in the eastern sky. Saturn is in opposition on March 7, about which time it rises at sunset and sets about the time of sunrise; the planet is visible throughout the night in the constellation of Leo. An annular eclipse of the sun takes place on March 18, but it is invisible in the British Isles. It can be seen over large portions of the southern hemisphere.

Spring equinox occurs on March 21d 05h when the sun enters the sign of the first point of Aries. It is scarcely necessary to remind readers that, while this sign was once in the constellation of Aries, this is no longer true, owing to the phenomenon known as the precession of the equinoxes, and is now in the constellation of Pisces. The old name "first point of Aries" still survives but it must not be imagined that the sun is in this constellation about March 21. Over all the earth at this time, and also at the autumnal equinox, the days and nights are of equal length—12 hours each, whatever the latitude may be, and the sun rises and sets exactly east and west, respectively.

The Bookshelf

Crucibles: The Story of Chemistry. By Bernard Jaffe. (Hutchinson's Scientific and Technical Publications, London, Third Edition revised and enlarged, 1949, pp. 480, 18*s*.)

BIOGRAPHIES of scientists have a very wide appeal and are capable of reaching a bigger readership than almost any other class of scientific book. *Crucibles*, which describes the lives of a number of great chemists, became a best-seller when it was first published in America in 1930 and it is indeed a pleasure to note the appearance of its third edition.

This edition deserves to be as successful as its predecessors, for the author has gone to immense trouble to collect a mass of biographical details to interest the many readers who can be deterred from reading books on scientific history that have no human interest because the story of discovery is treated impersonally and not as a record of human achievement. This book can be read with interest by anyone who has studied chemistry at school; certainly anyone who has gone to Inter. B.Sc. standard in chemistry should find it comfortable and pleasurable reading.

The book provides biographies of the following chemists: Trevisan, Parace lsus, Becher, Priestley, Cavendish, Lavoisier, Dalton, Berzelius, Avagadro, Woehler, Mendelieff, Arrhenius, Madame Curie, J. J. Thomson, H. G. F. Moseley, Irving Langmuir, E. O. Lawrence.

The final chapters are entitled "The Men Who Harnessed Nuclear Fission" and "Nuclear Energy Tomorrow". Even in the last two chapters most readers will come across points that are interesting because they are novel in so far as they have not been recorded in British journals. There is, for example, a vivid account of the starting of the first atomic pile. Not perhaps very important, but nevertheless interesting is the fact recorded in the book that the discovery of the new elements americium and curium was announced not to a scientific society *but on a radio quiz*! The announcement had been planned for a meeting of the American Chemical Society, but on the preceding Sunday Glenn Seaborg was the guest on a quiz programme; he was asked if any new elements had been discovered, and he was unable to resist this invitation to talk about Elements No. 95 and No. 96.

The Observer's Book of British Geology. By I. O. Evans, with foreword by Professor H. L. Hawkins, D.Sc., F.R.S., F.G.S. (Frederick Warne, London, 1949, pp. 266; with 182 illustrations in colour and black and white, 5*s*.)

FROM time to time geologists complain that the general public is ignorant about their work and its importance, but this is scarcely surprising when one considers how few publicists of this subject there are; it is very rare to meet a popular book, a popular article, or a radio broadcast dealing with a geological topic, while there is a more or less total lack of films on the subject. Perhaps this will remain the case as long as the geological profession remains a small profession and a busy one. (This fact only partially explains the shortage of a modern popular literature on geology; professional astronomers are scarcely more numerous than professional geologists, yet there is no lack of astronomical books that can be recommended to the layman.)

Thus there is something like a vacuum to be filled, and there can be no doubt that in the circumstances the publishers can expect a large sale for the very low-priced pocket-sized volume under review. It is simply written and the abundance of excellent illustrations (including twelve coloured plates) give it a popular appeal. The author might perhaps have done more to make his script attractive to the man in the street for which it is intended, but the subject matter of the book is perhaps exciting enough to justify him in providing a script to which the adjective 'elementary' rather than 'popular' should be applied.

There is every reason to anticipate that this book will be as successful as its predecessors in "The Observer's" series. When a new edition is called for the author should consider adding a book list that will help to satisfy the curiosity which this volume will arouse but could not possibly requite in view of its brevity.

M. SCHOFIELD.

Science Russian Course. By Maximilian Fourman. (London, University Tutorial Press Ltd., 1949, pp. 274, 10*s*. 6*d*.)

THE book is divided into three parts, presenting firstly an outline of Russian grammar, then a selection of extracts from contemporary Russian periodicals and textbooks relating to Physics, Chemistry, Mathematics, Botany, Zoology, Physiology and Medicine, and finally a Russian vocabulary.

The book is well produced and a perusal reveals no obvious mistakes. It is claimed that the book "is intended for students without any previous knowledge of the language who wish to read Russian scientific and technical literature". This claim is perhaps a little optimistic, although it is certainly surprising to find that a vocabulary consisting of only some 4000 words is adequate to cover about 180 pages of very varied Russian extracts.

The value of the book would be greatly enhanced if the Russian text were accompanied by explanatory notes pointing out peculiarities of the Russian language. A much more serious omission, however, is the absence of accents in the Russian text. Admittedly, this book is not intended to serve as a text-book of the Russian language, nevertheless anyone using it undoubtedly will memorise some of the words. This in itself is a very desirable thing, and surely some guidance should be given to the readers upon correct accenting which, incidentally, is one of the most difficult aspects of the Russian language.

V. L. RASTORGOUEFF.

Two Mountains and a River. By H. W. Tilman (Cambridge, University Press, 1949, pp. 231, 21*s*.)

IN this book, H. W. Tilman presents a traveller's tale which is more than just a description of part of the Himalayas. His first objective was *Rakaposhi* (25,550 ft.) in the *Karakoram* range, and his second *Muztagh Ata* "Father of Ice Mountains" (24,388 ft.) in Sinkiang.

Although he did not reach the summit of either, there is no feeling of frustration in his description of the attempts. His ability to appreciate the minor incidents and the personalities of lesser characters gives this book a quality which sustains the interest all the way through. The "River" of the title is the Oxus and is incidental to the return journey from Kashgar. The author's wide outlook seems typified in the world-wide sources of his nicely chosen quotations and the standard of photography is excellent throughout.

American Wild Flowers. The New Illustrated Naturalist, by Harold N. Moldenke. (Macmillan & Co. London, Van Nostrand, New York, 1949, pp. 453; illustrated with 88 photographs in full colour and 67 in gravure, 35*s*.)

BRITAIN'S "New Naturalist" series of books has its counterpart in the United States. The American series is known as "The New Illustrated Naturalist", has a distinguished editorial board and makes the greatest possible use of first-class illustrations (including many made from colour photographs). *American Wild Flowers* is a good example of what is being attempted in this series, and must be recognised as something of a tour de force for it describes the natural history of 2000 'principal' species of flowers occurring in the United States. The U.S. flora includes more than 32,000 species, so it can have been no easy matter for the author to decide which species ought to be mentioned and which ought to be left out. One hopes that a British publisher will at least consider publishing a similar book; as the number of British species is about equal to the number of species dealt with in Moldenke's book, it should be possible to produce an excellent popular 'flora' covering *all* the British species. Such a book should find a niche since no comprehensive popular flora using modern methods of illustration has appeared in this country so far as this reviewer is aware.

The Face of the Moon. By Ralph B. Baldwin (University of Chicago Press, Chicago; Cambridge University Press, London, 1949, pp. 239, 40*s*.)

THE author believes that the craters on the moon are the result of bombardment by meteorites. This provocative idea, which was discussed in DISCOVERY recently (September 1949, p. 271), is here developed in detail by Dr. Baldwin, with a wealth of figures and excellent illustrations.

Printed and Published in Great Britain by Jarrold & Sons, Ltd., Norwich. *Editorial Offices: 244 High Holborn, W.C.1.*

CRUCIBLES
The Story of Chemistry
by BERNARD JAFFE

(Third edition)

One of our eminent professors of chemistry says of this book: "It is really a history of chemistry which I would unhesitatingly recommend to a student and which I believe a great many laymen would like to read for its cultural and at the same time glowing interest." 18*s*.

LIGHTING TECHNIQUE
by Professor B. F. FEDOROV and W. T. O'DEA, B.Sc.

A study of the whole science of illumination, with additional sections on fluorescent lighting by an English authority. Illustrated. 25*s*.

PRINCIPLES OF AGRICULTURE
by Professor W. R. WILLIAMS

The author was one of the founders of modern Soviet agriculture and his ideas and theories as expounded in this book have exercised a wide and beneficial influence. This translation by G. V. Jacks, M.A., B.Sc., Director of the Commonwealth Bureau of Soil Science, is the only one available to English readers. Illustrated 15*s*.

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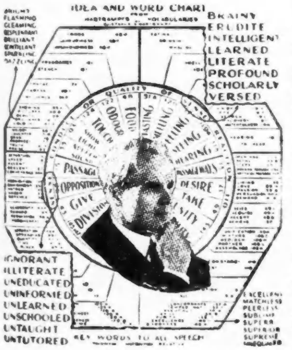

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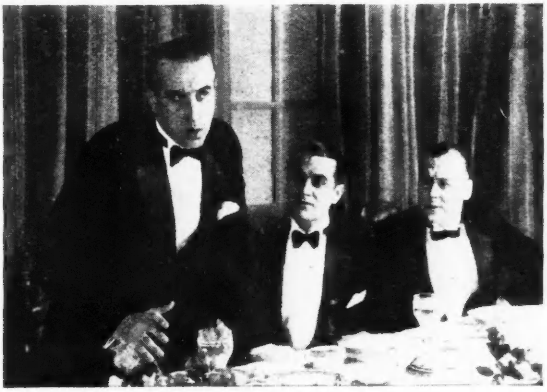

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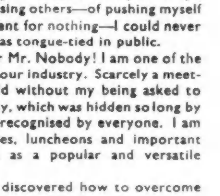

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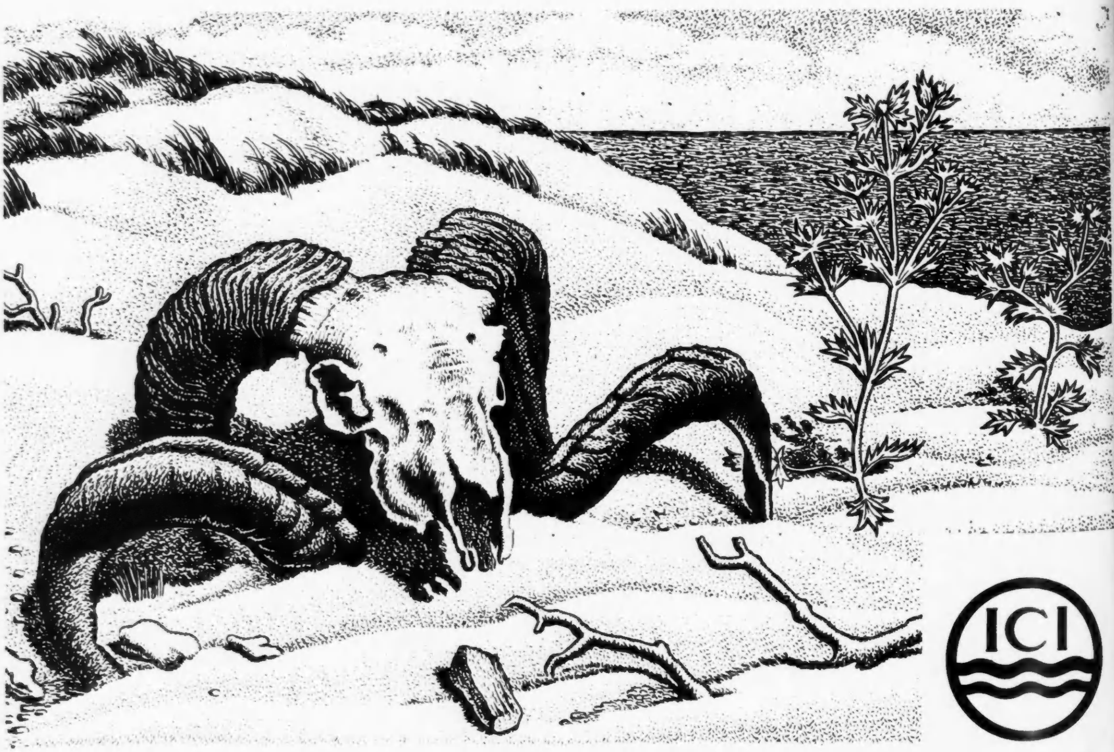
The chemical industry's achievement in respect of chlorine is one of production. The consumption of chlorine has increased steadily since its discovery in 1774, and in recent years great efforts have been necessary to meet the ever-growing demands for this important chemical. Chlorine is one of the most reactive of the elements and, for this reason, it is never found free in Nature. In 1799, Charles Tennant of St. Rollox Works, Glasgow, combined it with lime to produce bleaching powder, and from that day forward, chlorine and its derivatives became intimately associated with the progress of industry. Now, in liquid or gaseous form, this versatile chemical is required in enormous quantities for the bleaching of paper and textiles, for sterilising water supplies, and for the manufacture of acids, disinfectants, drugs, plastics, refrigerants, solvents and countless other important chemicals, including the powerful 'Gammexane' insecticides.

Today most chlorine is produced by passing an electric current through brine. This process yields caustic soda and hydrogen as well as chlorine. Caustic soda is itself a valuable product, and the hydrogen may be combined with chlorine in a separate process to yield hydrochloric acid — yet another chemical of the utmost value to modern industry.



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